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BRITISH COLUMBIA DEPARTMENT OF MINES

HON. W. K. KIERNAN, *Minister* P. J. MULCAHY, *Deputy Minister*

BULLETIN No. 41

Stratigraphy and Structure of the Salmo Lead-Zinc Area

by

JAMES T. FYLES and C. G. HEWLETT

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Cecil George Hewlett, co-author of this bulletin, fell to his death on August 14th, 1957, in the East Kootenay District while engaged in geological mapping for the British Columbia Department of Mines.

Before starting the present study in 1952, Dr. Hewlett had spent the greater part of three field seasons in the district, one with the Geological Survey of Canada and two with New Jersey Zinc Company, from 1947 to 1949. His familiarity with the district, boundless energy, and a facility for continually re-examining conclusions as the work progressed made his contribution to this bulletin invaluable. Dr. Hewlett's name is perpetuated in Hewlett Peak, a summit at the head of Active Creek about 7 miles southeast of Ymir.

This bulletin is the result of about ten years of planning and execution. Field work engaged the senior author for half a season and both authors for an additional four seasons and a half. Dr. Hewlett's untimely death before the work was fully compiled naturally has placed a heavy additional load on the shoulders of the senior author. It is hoped that this presentation, which contains a great deal of information and a number of entirely new concepts, will be valuable to an important mining district.

H. Sargent,
Chief, Mineralogical Branch.

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Stratigraphy and Structure of the Salmo Lead-Zinc Area

SUMMARY

1. The area referred to in this report as the Salmo lead-zinc area, or simply as the map-area, is within the classic Salmo Area in the Nelson Mining Division of southeastern British Columbia.

2. The map-area is near the southern end of the Kootenay arc, a curving structural belt of sedimentary rocks extending southeast from near Revelstoke, south along Kootenay Lake, and southwest across the International Boundary. A point of pronounced curvature occurs within the map-area.

3. The Salmo Area contains late Precambrian and early Palæozoic sedimentary and metamorphic rocks, Mesozoic volcanic rocks, and late Mesozoic and Tertiary granitic rocks. The present study has been mainly of the Palæozoic rocks because essentially all the known lead-zinc deposits are in rocks of Cambrian age.

4. Four Cambrian formations—the Quartzite Range, Reno, Laib, and Nelway—have been named. The Quartzite Range and Reno are dominantly quartzitic, the Laib is an argillaceous formation containing prominent limestone members, and the Nelway is a thick unit of limestone and dolomite. The orebearing Reeves limestone is in the lower part of the Laib formation. These formations make up a conformable sequence which conformably overlies late Precambrian sedimentary rocks.

5. Black argillite of the Active formation of Ordovician age overlies the Nelway formation with probable disconformity.

6. The map-area is divided into four belts trending northeast and north. These are, from west to east: (1) the Mesozoic Volcanic Belt, (2) the Mine Belt, (3) the Black Argillite Belt, and (4) the Eastern Belt. The belts are intruded irregularly by several granitic stocks. They are separated by three eastward and southward dipping regional thrust faults. The Mine and Eastern Belts contain the Cambrian formations, and the Argillite Belt contains the Ordovician Active formation.

7. The map-area is structurally very complex. Overturned and isoclinal folds, called " primary," are the oldest known structures. These folds have been folded into structures called " secondary," which are considered to have formed late in the same general period of deformation as the primary folds.

8. Bedding and thrust faults are common. They probably originated late in the period of primary folding and continued to be active during the secondary folding.

9. Granitic stocks cut the primary and secondary structures. Complex folds around the margins of some of the stocks are referred to as late cross-folds.

10. Transverse faults offset the primary and secondary structures and some offset the late cross-folds.

11. Regional thrust faults that separate the belts conform to the curvature of the southern part of the Kootenay arc. In the northern part of the map-area the faults strike northward and dip steeply eastward; toward the south they change in strike to eastward and in dip to gently southward.

12. Axes of primary folds also follow the regional trend of the arc. In the northern part of the area, east of the Salmo River, the axes strike northward, farther south they strike northeastward, and to the southwest along the Pend d'Oreille River they strike eastward.

13. Primary fold axes plunge mostly at small angles to the south and southwest, but locally they plunge to the north. Axial planes in general dip eastward and southward.

14. The Sheep Creek anticline dominates the structure of the Eastern Belt. The anticline plunges gently, in general to the south, but locally to the north. It is intruded by

the Lost Creek stock, north of which the anticline is isoclinal and has a subsidiary syncline and anticline on its western flank. South of the stock the anticline is simple and more open than to the north.

15. In the Black Argillite Belt, the structural pattern is one of isoclinal folding and related shearing. No major folds and faults have been recognized. Foliation in general dips eastward and southward. Small folds have complex shapes and vary in strike and dip of axial plane and in plunge over relatively small areas.

16. In the southern part of the Mine Belt the most prominent primary structure is the Salmo River anticline. It is an isoclinal anticline, with axial plane dipping steeply to the south and axis probably plunging at a low angle to the west. Dragfolds related to secondary structures are superimposed on the Salmo River anticline. They plunge steeply to the southwest and have the shape of a letter " Z " in plan, indicating a relative movement of the south side of the area westward. Bedding faults are common. They probably originated during the primary folding as thrust faults, but during the secondary deformation strike slip was dominant.

17. In the central part of the Mine Belt the dominant primary structure is the Jersey anticline. It is a complex isoclinal fold with axis striking about north 15 degrees east and plunging at low angles to the north and to the south. The axial plane dips steeply east on the eastern side of the Mine Belt and flattens to the west until the anticline is recumbent. The right-side-up eastern limb appears to have ridden over the overturned limb on a series of bedding faults. The fold has been folded into secondary open anticlines and synclines with axes essentially parallel to the axis of the Jersey anticline.

18. In the northern part of the Mine Belt north of the Hidden Creek stock the largest primary fold recognized is an isoclinal anticline, the Jack Pot anticline. The axial plane dips steeply to the east and the axis plunges at a low angle to the south. It is flanked on the east by a smaller isoclinal syncline and broken by many complex bedding faults. Secondary folds probably plunge parallel to the primary folds.

19. Structural patterns in the map-area suggest that the primary and secondary structures developed by continued application of one set of regional stresses. In the northern part of the map-area, movement of east over west is suggested by the eastward dip of axial planes of primary folds and bedding faults. Continued movement in the same direction is suggested by the fact that the secondary fold axes are parallel to the primary fold axes. In the southern part of the map-area continued movement toward the west during secondary deformation gave steeply plunging folds and strike-slip movement on bedding faults.

20. Present production in the map-area is of lead-zinc and tungsten ore. Only lead-zinc mineralization is discussed in the present study.

21. The principal lead-zinc deposits are in the Mine Belt and include the Reeves MacDonald, Jersey, and H.B. mines. The deposits are replacements of sphalerite, galena, and pyrite in dolomitized zones in the Reeves limestone. Mineralized zones are elongate, and tabular or lenticular in cross-section. The largest are a few thousand feet long, a few tens of feet thick, and a few hundred feet wide.

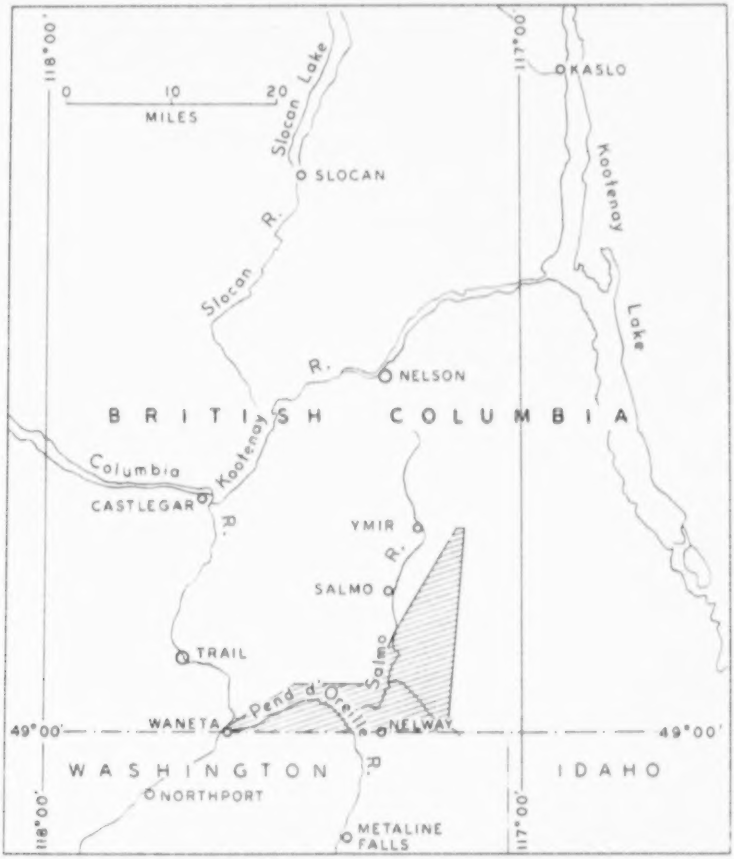
22. The deposits are structurally controlled. The Reeves orebody at the Reeves MacDonald mine is in a steeply plunging secondary syncline on the south limb of the Salmo River anticline. The Jersey orebodies follow secondary folds and locally bedding faults on the right-side-up limb of the Jersey anticline. The H.B. orebodies plunge parallel to primary and secondary fold axes and some are along gently dipping faults.

23. Dolomite has been a favourable host rock for mineralization. All the orebodies are in dolomitized zones in the Reeves limestone; little mineralization has been found in limestone that has not been dolomitized.

24. Dolomite zones in the Reeves limestone are structurally controlled epigenetic replacements. They are close to and on the footwall side of the Argillite fault. Dolomitization preceded granitic intrusion; the relative age of the sulphide mineralization and granitic intrusion is uncertain.

CHAPTER I.—INTRODUCTION

The Salmo lead-zinc area is in the Nelson Mining Division of southeastern British Columbia (*see* Fig. 1). The mines are in a belt of lead-zinc mineralization extending from the International Boundary west of the border crossing point of Nelway to the vicinity of Porcupine Creek, 18 miles north of the boundary. The principal community is the village of Salmo, on the west side of the area 13 miles north of the boundary. Salmo is on the Nelson–Fort Sheppard branch of the Great Northern Railway and the Nelson–Nelway highway, a branch of which runs west to Trail. It is 26 miles by road south of Nelson and about the same distance east of Trail.


118°00'
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10
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MILES
Slocan Lake
SLOCAN
Slocan R.
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KASLO
Kootenay Lake
R.
NELSON
BRITISH COLUMBIA
Columbia
Kootenay R.
CASTLEGAR
YMIR
R.
SALMO
Salmo
TRAIL
Pend d'Oreille R.
WANETA
NELWAY
49°00'
49°00'
WASHINGTON
IDAHO
NORTHPORT
METALINE FALLS
118°00'
117°00'

Figure 1. Index map showing location of the map-area.

Geologically, the Salmo lead-zinc area is near the southern end of a structural belt that extends southeast from Revelstoke, south along Kootenay Lake, and southwest across the International Boundary. It has been referred to as the Kootenay arc and may be described as a curving belt of heterogeneous lime-bearing sedimentary rocks bowed around the eastern margin of a major batholithic area. The lime-bearing rocks are of early Palæozoic age and are bounded on the east by underlying late Precambrian quartzites. These early Palæozoic and late Precambrian rocks form the westernmost limit of sedimentary rocks of these ages in southern British Columbia. The batholithic area includes the Nelson batholith and related stocks in the south, and the Kuskanax batholith in the north, both of which are Mesozoic or younger. The Salmo map-area covers part of the arc in which the regional strike changes, in going to the south, from south to southwest. The area (*see* Figs. 2 and 3) comprises two strips of country, one along the International Boundary from Waneta to Nelway, and the other east of Nelway, extending north from the boundary to the ridge north of Oscar Creek. The map-area is mainly within the classic Salmo Area (*see* Walker, 1934; Little, 1950), but the part along the lower Pend d'Oreille River is west of the Salmo Area and that between Porcupine and Oscar Creeks is north of it.

Topographically, the map-area is dominated by the Salmo and Pend d'Oreille Rivers. The Salmo River flows in a valley lying between the southern end of the Nelson Range on the east and the southern end of the Bonnington Range on the west. The valley is as much as a mile wide for most of its length and drops from an elevation of about 2,500 feet at Ymir to about 1,700 feet at its junction with the Pend d'Oreille River. The Pend d'Oreille River, with an elevation of about 1,700 feet at the International Boundary, joins the Columbia River at an elevation of 1,300 feet, and throughout its length flows through rocky canyons at the bottom of a narrow valley. East of the Salmo River the hills rise abruptly to elevations of about 5,000 feet, then continue to rise more gently to the 7,000-foot summits of Lost Mountain, Mount Waldie, and Reno Mountain. The deep valleys of Porcupine Creek, Hidden Creek, Sheep Creek, Lost Creek, and the South Salmo River cut abruptly across the northerly trend of the mountain ridges.

Most of the map-area can be reached by roads from the Salmo or Pend d'Oreille Valleys. Good gravel roads extend from the Nelson–Nelway highway to all the mines and many of the prospects. Logging-roads are numerous in the southern part of the area along the Pend d'Oreille River. Many of the latter are temporary, but all the roads and trails known to the writers and accessible between 1951 and 1956 are shown on Figure 3.

The district has been thoroughly burned over and a thick tangle of buckbrush, aspen, and jack pine has grown up. The chief areas of commercial timber that remain are along the Pend d'Oreille River and the lower reaches of the Salmo River. Small sawmills are located on McCormick Creek, Tillicum Creek, Slate Creek, near Charbonneau Creek, and near Church Creek in this area. Some timber has also been cut on Bennett Creek, the upper part of Sheep Creek, and on Oscar Creek. The high ridges east of the Salmo Valley are largely grass covered and support sparse stunted trees.

The abundance of outcrops in the map-area varies considerably. Continuous exposures are found along the canyons of the Pend d'Oreille and the lower Salmo Rivers and on the high peaks in the eastern part of the area. Gravel terraces conceal bedrock along the main Salmo Valley and the larger tributary streams, but outcrops above the terraces are reasonably abundant. The amount of outcrop depends to some extent on the rock type. Limestone and quartzite generally outcrop well, but phyllite and argillite commonly outcrop poorly. Large areas of very poor outcrop underlain by soft phyllite and argillite lie along the International Boundary south of the South Salmo and Pend d'Oreille Rivers.

HISTORY

The history of the Salmo lead-zinc mining district is closely associated with developments in the Ymir gold camp a few miles to the north (*see* Drysdale, 1917) and the Sheep Creek camp immediately to the east (*see* Mathews, 1953, p. 65). The early history of the Salmo Area, from the first discovery of placer gold on the Salmo River in 1865 until 1932, is described by Walker (1934). In this period placer-mining on the Pend d'Oreille and Salmo Rivers attracted most attention until the 1890's, when lode gold was first produced at Sheep Creek. Mining continued at Sheep Creek until 1916, after which time the camp was largely inactive until 1928. The first lead ore in the district was mined in 1906 at the old Emerald mine, and production from high-grade shoots of galena continued until 1926. A few tons of ore was mined and milled on the Jersey claim near the old Emerald in 1919. Lead-zinc carbonate ore was mined at the H.B. in 1912. About 200 tons of molybdenite ore was shipped from the Molly mine in the period 1914 to 1917. A renewed interest in gold revived the Sheep Creek camp in 1928, and production continued until 1951, when the last mine closed. The discovery of tungsten on Iron Mountain in 1941 led to the production of tungsten concentrates from the Emerald mine in 1943, and in a second period starting in 1947. The more recent interest in the lead-zinc deposits of the area started about 1946, when the Reeves MacDonald mine was prepared for production and diamond drilling was done on the Jersey orebodies. The Truman prospect was drilled in 1947, and drilling programmes were started on the H.B. in 1948 and on the Jack Pot in 1949. By 1952 most of the accessible limestone in the Salmo Area had been staked, and several thousand feet of drilling was done " blind " or based on scanty geological information. As a result of the exploration since 1946, the H.B., Jersey, and Reeves MacDonald mines were brought into production and the Jack Pot became a potential producer.

The Jersey mine has produced lead and zinc continuously since early in 1949. The Reeves MacDonald began producing during the summer of 1949 but closed between June, 1953, and October, 1955. At the H.B., oxidized ore was mined intermittently between 1912 and 1950. Sulphide orebodies were developed and a flotation mill was ready for operation by the early part of 1953, but production was deferred until the spring of 1955.

GEOLOGICAL WORK

The first comprehensive geological map of the Salmo Area was prepared by John F. Walker in 1928, 1929, and 1931 and published in 1934 with Memoir 172 of the Geological Survey of Canada. Prior to this work the area was included in the West Kootenay sheet of McConnell and Brock (1904), and the southern part was covered by Daly (1912) in his reconnaissance along the 49th parallel. The two earlier maps are mainly of historical interest. Walker (1934) established the main rock units recognized to-day and provided the only complete description of mineral properties in the area. Geological work in the adjoining Metaline quadrangle of northeastern Washington by C. F. Park and R. S. Cannon has influenced the more recent studies. Mapping of the Nelson (west half) sheet for the Geological Survey of Canada by H. W. Little led to revisions of Walker's map of the Salmo Area. This work was carried on in 1947, 1948, and 1949, during part of which time palæontological and stratigraphic studies of the early Palæozoic rocks were made by V. J. Okulitch, and mapping of the Ymir area was done by A. L. McAllister. The results of these studies were included in Preliminary Papers 49-22, 50-19, 51-4, and 56-3, published by the Geological Survey of Canada. Detailed investigations in the Sheep Creek camp in 1948 and 1949 by W. H. Mathews, of the British Columbia Department of Mines, led to the publication of Bulletin No. 31 in 1953. The present map-area (Fig. 3) is completely covered by maps of the Geological Survey of Canada and adjoins the map of the Sheep Creek camp on the west.

Except for a surface geological map of the Reeves MacDonald mine prepared by J. J. O'Neill in 1928 and 1930, geological mapping by mining companies has been carried out since about 1940. In 1941 a geological map of the Emerald-Jersey area was prepared under the direction of Harold Lakes (*see* Little, 1953). Geologists of The Consolidated Mining and Smelting Company of Canada, Limited, did plane-table mapping of selected areas between the H.B. mine and Lost Creek from 1946 to 1951. New Jersey Zinc Company did detailed mapping on the Truman claims between Lost Creek and the South Salmo River, regional mapping between the South Salmo River and the International Boundary in 1947, and did detailed mapping in the vicinity of Porcupine Creek from 1948 to 1950. An area south of the Pend d'Oreille River was mapped by Diem

Mines Limited in 1947 on a scale of 1,000 feet to the inch (*see* Shenon and Full, 1947). In 1953 and 1954 The American Metal Company studied an area immediately west of the Sheep Creek camp and prepared geological maps on a scale of 300 feet to the inch (*see* Moorhouse, 1953). Geological maps of relatively small areas have also been prepared by company geologists for the Red Bird, Victory Tungsten, Aspen, and Alps properties.

The programme of geological mapping that forms the basis of this report was started by J. T. Fyles in 1951 and continued by both authors during the summers of 1952, 1953, 1954, 1955, and part of 1956. During 1951, field work for the preparation of a new topographic map on a scale of 1,000 feet to the inch with 50-foot contours was carried out by the British Columbia Department of Lands. In 1952 and 1953 most of the regional geological map (Fig. 3) was made, using this new base. Geological features were located by pace and compass traverses, compass resections, barometric observations, and radial line plotting of selected points recognized on the air photographs. The magnetic declination was taken as north 22 degrees east. Claim boundaries shown on Figure 3 were plotted from enlargements of mineral reference maps adjusted to available control. The locations of only a few claim boundaries have been checked in the field. Most of the 1954 field season was spent on 200-scale plane-table mapping at the Reeves MacDonald and Jersey mines, and the 1955 season on similar mapping in the vicinity of the H.B. mine and on Porcupine Creek. The writers spent the month of June, 1956, in detailed underground mapping at the Jersey mine. Parts of the maps of the Jersey (Fig. 9) and of the H.B. mines (Fig. 7) and most of the map of the Jack Pot property (Fig. 8) are based on company geological plans. When company plans and drill data were used, all outcrops were visited by the writers and all available drill core was logged.

The writers have attempted to examine all the lead-zinc prospects in the area mapped. The cores of a number of exploratory diamond-drill holes drilled in unmineralized areas were made available to them, and the logs are published in the appendix to this report. The location of the holes is shown on Figure 3.

ACKNOWLEDGMENTS

The writers were assisted in the field by S. A. Endersby in 1951; K. Finnigan, R. V. Rowley, and L. Sereno in 1952; Gordon Dods and L. Sereno in 1953; Harvey Jim and W. A. Padgham in 1954; and by M. J. Fraser and J. J. Twiss in 1955. One of the greatest aids in the execution of this project has been the complete co-operation of all the mining companies in the district in placing mine records, surveys, and geological information at the disposal of the writers and in providing accommodation when needed. Because the aim of the study was to solve existing problems of structure and stratigraphy, the writers made a point of discussing these problems with as many of the geologists as possible who had worked in the area. Helpful suggestions were made by company geologists, particularly W. O. Pollock, of Reeves MacDonald Mines Limited; L. Adie, C. C. Rennie, and T. S. Smith, of Canadian Exploration Limited; J. Richardson and G. F. Warning, of The Consolidated Mining and Smelting Company of Canada, Limited; R. C. MacDonald and H. C. Gunning, of New Jersey Zinc Explorations Limited; and by W. W. Moorhouse, of The American Metal Company of Canada Limited. Discussion and field excursions with H. W. Little and L. H. Green, of the Geological Survey of Canada, and suggestions by W. H. Mathews, of the University of British Columbia, were of value. Geological studies in the Metaline quadrangle under the direction of M. G. Dings and in Stevens County by R. G. Yates, of the United States Geological Survey, were being carried out while the writers were in the field. The close co-operation of these two men in arranging discussions and field trips and in adjusting the geological maps along the International Boundary is gratefully acknowledged.

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CHAPTER II.—GENERAL GEOLOGY

INTRODUCTION

The Salmo Area contains late Precambrian and early Palæozoic sedimentary and metamorphic rocks, Mesozoic volcanic rocks, and late Mesozoic and Tertiary granitic rocks. The western and northern limit of the Palæozoic rocks is approximately along the Salmo and Pend d'Oreille Rivers. Mesozoic volcanic rocks underlie large areas west of the Salmo and north of the Pend d'Oreille, and do not occur to the east or south. Large granitic stocks of the Nelson intrusions and smaller ones, probably of Tertiary age, cut the older formations. A complete sequence of all the rocks in the Salmo Area is not found in the present map-area. Table I gives the stratigraphic sequence within the map-area. Precambrian rocks beneath the Quartzite Range formation lie east of the map-area, and Mesozoic rocks lie mainly west and north of it.

Table I.—Table of Formations

Era	Period	Group or Formation	Lithology
Cenozoic.	Tertiary (?).		Granite, syenite, and monzonite; lamprophyre dykes.
Mesozoic.	Relationship not known.		
	Cretaceous (?).	Nelson intrusions.	Granitic stocks.
	Intrusive contact.		
	Jurassic and (?) Cretaceous.	Beaver Mountain formation.	Mainly volcanic rocks.
	Stratigraphic relationship not established within the map-area.		
	Triassic and (?) earlier.	Ymir group.	Black argillite and argillaceous quartzite.
Palæozoic.	Stratigraphic relationship not established within the map-area.		
	Ordovician.	Active formation.	Black argillite, slate, and argillaceous limestone.
	Stratigraphic relationship not established within the map-area.		
	Middle Cambrian.	Nelway formation.	Grey dolomite and limestone.
		Gradational contact.	
	Lower Cambrian.	Laib formation.	Phyllite and limestone.
		Conformable contact.	
		Reno formation.	Micaceous quartzite.
		Conformable contact.	
		Quartzite Range formation.	White and micaceous quartzite.

The present study has been mainly of the Palæozoic rocks because essentially all the known lead and zinc deposits are in complexly deformed limestone near the base of the Laib formation. Intensive geological mapping has been restricted to areas near the lead-zinc deposits and to rocks stratigraphically close to those in which they are found. Other sedimentary rocks have been mapped in less detail. Only the contact relationships of granitic and volcanic masses were investigated. Although the study has been mainly of the mineralized areas, a knowledge of the regional relationships has been essential to an understanding of the structural complexities. Many of the conclusions are of regional significance.

The map-area is divided into four areas or belts (*see* Fig. 2). These are, from west to east: (1) The Mesozoic volcanic area, (2) the lead and zinc Mine Belt, (3) the Black Argillite Belt, and (4) the Eastern Belt. The four belts have been named for descriptive purposes, but they are also geologically significant because they are separated by three eastward and southward dipping regional thrust faults. They are defined without regard for the granitic masses that cut irregularly across them. The Mesozoic volcanic area lies mainly west of the Salmo and north of the Pend d'Oreille Rivers. It forms most of the northwestern half of the Salmo Area (*see* Little, 1950, Map 50–19A), and only the eastern and southern edges of it are shown on the accompanying maps. The lead and zinc Mine Belt, or simply the Mine Belt, bounds the volcanic area on the east and south. It is a curved belt 2 to 5 miles wide, including all the known major lead-zinc deposits, from the Jack Pot near its northern end to the Reeves MacDonald on the Pend d'Oreille River, and extending westward along the river and across the International Boundary. The Black Argillite Belt includes an area up to about 2 miles wide, underlain mainly by black argillite and lying east of the Mine Belt. It separates Cambrian rocks of the Mine Belt from their correlatives in the Eastern Belt. The Eastern Belt extends from the northern end of the Sheep Creek gold-mining camp south to the International Boundary and west to the Pend d'Oreille River. An eastern boundary to the Eastern Belt has not been set.

PALÆOZOIC FORMATIONS

The Palæozoic rocks in the Salmo Area comprise a thick sedimentary sequence which has been highly deformed and at places has been greatly changed by thermal metamorphism. All of the rocks show secondary structures resulting from deformation, and in many places these structures obscure the sedimentary characteristics. Four Cambrian formations—the Quartzite Range, Reno, Laib, and Nelway—have been named. The Quartzite Range and Reno are dominantly quartzitic, the Laib is an argillaceous formation containing prominent limestone members, and the Nelway is a thick unit of limestone and dolomite. These formations make up a conformable sequence which conformably overlies rocks generally considered to be late Precambrian (*see* Little, 1950, p. 10). The Nelway formation at the top of the sequence is overlain, probably disconformably, by black argillite of the Active formation, of Ordovician age.

Present knowledge of the stratigraphic succession has come from a number of investigations carried out over a period of years. The original subdivisions proposed by Walker in 1934 have been modified (*see* Table II). In the Metaline quadrangle south of the Salmo Area, few of the subdivisions made by Park and Cannon corresponded to those in the Salmo Area (*see* Park and Cannon, 1943, p. 6). Fossils were found in the Metaline quadrangle in rocks equivalent to those that Walker had included in the Pend d'Oreille series and regarded as late Precambrian. Subsequently, Little found fossils in the Salmo Area and subdivided the Pend d'Oreille series to conform with the rock units in the Metaline quadrangle, but introduced the new names Laib group, and Nelway and Active formations. The work of Mathews (1953) in the Sheep Creek mining camp clarified Walker's definition of the Reno formation and led to subdivision of the Quartzite Range formation. In the present study, only minor changes have been made in the previous terminology and subdivisions. The Laib group is redefined as a formation with

Table II.—Correlation Table

Walker (1934)	Park and Cannon (1943)	Little (1950)	Mathews (1953)	Fyles and Hewlett
	Ledbetter slate (Ordovician).	Active formation (Ordovician).		Active formation.
Pend d'Oreille series.	Metaline limestone (Middle Cambrian).	Nelway formation (Middle Cambrian).		Nelway formation.
	Maitlen phyllite.	Laib group (Lower Cambrian).	Laib group.	Laib formation. Upper Laib (undivided). Emerald member. Reeves member. Truman member.
Reno formation.	Gypsy quartzite.	Reno formation.	Reno formation. Upper Reno. Lower Reno.	Reno formation. Upper Reno. Lower Reno.
Quartzite Range formation.		Quartzite Range formation.	Quartzite Range formation. Navada member. Upper Navada. Lower Navada.	Quartzite Range formation. Navada member. Upper Navada. Lower Navada.
			Nugget member. Upper Nugget. Middle Nugget. Lower Nugget.	Nugget member. Upper Nugget.
			Motherlode member.	

the Reno-Laib boundary, the same as that defined by Mathews* (1953, p. 22), and the formation has been subdivided into members. The Reno-Laib boundary appears to correspond approximately to the Gypsy-Maitlen boundary in the Metaline quadrangle, as described by Park and Cannon (1943, p. 15). The terminology and correlations of lower Palæozoic rocks in the Salmo Area and Metaline quadrangle are summarized in Table II. The present work has not led to major revisions of the stratigraphy, but detailed knowledge of the stratigraphy has made possible better correlations and a more accurate map.

Fossils are very rare in Palæozoic rocks of the map-area. Lower Cambrian pleosponges were collected by Little (1950, p. 17) in the Reeves limestone about 4 miles east of the Sheep Creek anticline. Two poorly preserved specimens of similar fossils were found by the writers on the Sheep Creek anticline. The localities are shown on Figure 3. No fossils have been found below the Reeves limestone in the Salmo Area, but several poorly preserved fragments of Cambrian trilobites are reported by Park and Cannon (1943, p. 15) to have been found in Gypsy quartzite about 2 miles south of the International Boundary and just east of 117° 10′ west longitude.

Middle Cambrian fossils from the lower part of the Metaline limestone are described by Park and Cannon (1943, p. 19) and by Okulitch (*see* Little, 1950, p. 20). These fossils, mainly trilobites, were collected near Metaline Falls, Washington, about 10 miles south of the International Boundary. Three poorly preserved fossil fragments are reported by Little (1950, p. 21) from the Nelway formation in the Salmo Area.

Ordovician fossils, mainly graptolites, were discovered by Little at the type locality of the Active formation between Active and Porcupine Creeks (*see* Little, 1950, p. 23). No other Ordovician fossils have been found in the map-area, even though rocks of the Active formation underlie large parts of it. South of the International Boundary, graptolites have been found at a number of localities in the Metaline quadrangle (*see* Park and Cannon, 1943, p. 21) and in the Leadpoint quadrangle to the west (*see* Yates, 1956).

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* Little (1950, p. 15) placed the base of the Laib group at the base of the Reeves limestone, but Mathews' definition required the boundary to be at the base of the Truman member.

Because of the scarcity of fossils in the map-area, stratigraphic correlations are lithologic. Correlations are based on matching of the stratigraphic succession, recognition of distinctive markers, and the general lithology of individual rock units. Although correlation is complicated by metamorphic changes, and to a much smaller extent by primary sedimentary facies changes, the rock types are sufficiently distinct and the succession is well enough known that in most cases correlations are beyond question.

The map-area is one of structural complexity. Isoclinal folding, shearing, and rock flowage have brought about great changes in the thickness and continuity of rock units. Knowledge of the stratigraphy depends on knowledge of the structure, and both stratigraphy and structure have been worked out together. The original stratigraphy cannot be reconstructed with accuracy because of structural complications. Localities at which typical sections of the Cambrian sequence are exposed were selected after the structure was known and most of the area was mapped. These sections, which are summarized in Table III, are homoclinal and are described as they appear on the ground.

CAMBRIAN ROCKS

Cambrian rocks in the Salmo Area comprise a conformable sequence of sedimentary rocks between 6,000 and 9,000 feet thick. They conformably overlie a thick sequence of unfossiliferous clastic sedimentary rocks of the Windermere system (*see* Little, 1950, and Rice, 1941) and are overlain by Ordovician black argillite and slate. Cambrian rocks in the map-area are exposed within the Mine Belt and the Eastern Belt (*see* Fig. 2), which are separated by the Black Argillite Belt. The stratigraphy in the Eastern Belt has been known for some time, but positive correlation between this stratigraphy and that in the Mine Belt has been possible only as a result of the present study.

One of the most complete sections of Cambrian rocks is in the Eastern Belt, on the southern part of the Sheep Creek anticline (*see* p. 76). Quartzites of the Quartzite Range formation at the core of the anticline and the overlying calcareous rocks of the Laib formation are exposed on the south side of the South Salmo River between 4 and 5 miles from its confluence with the Salmo River. Phyllite and calcareous rocks of the Upper Laib and Nelway formations underlie the gentle upland country between the South Salmo Valley and the International Boundary. The section given in Table III was measured on the south side of the South Salmo River on the ridges west and east of Rainy Creek. Rocks in the lower part of the section form open bluffs on the west side of Rainy Creek; those in the upper part are poorly exposed and the best section is on the east side of Rainy Creek. The beds dip 35 to 45 degrees southward and lie southeast of the crest of the Sheep Creek anticline.

In the Mine Belt complete sections of the Cambrian rocks have not been found. The most complete and least deformed section in the Mine Belt is on Truman Hill. It is summarized in the lower part of the composite section in Table III and was measured on the north and northwest slope of Truman Hill, starting on Lost Creek about 2,500 feet up the creek from the Lost Creek road bridge (*see* Plate IV). Rocks below the top of the Reno quartzite are exposed in bluffs, and those above the Reno can be seen best on the steep slope immediately northwest of the top of the hill. The rocks dip 35 to 40 degrees southeastward, and the structure is relatively simple. The lower part of the Reeves limestone is the highest member exposed on Truman Hill, and the remainder of the succession of Table III has been measured south and west of the Emerald mine, in a section that is overturned.

In the southwestern part of the map-area the Cambrian section is most easily examined at the Reeves MacDonald mine, but it is also well exposed and accessible north of the road along the Salmo River and east of Wallack Creek. In Table III the section from Nugget quartzite to Reeves limestone was measured in the River Tunnel of the Reeves MacDonald mine west of the B.L. fault, and the section from Reeves limestone to the Upper Laib formation was measured along the Pend d'Oreille River near the mouth of the Salmo.

Table III.—Columnar Sections of the Cambrian Rocks

Formation	Member	Sheep Creek Anticline, South Side of South Salmo River		Truman Hill-Emerald Mine Area, Composite Section		Reeves MacDonald Mine Area, Composite Section	
		Approximate Thickness (Feet)	Lithology	Approximate Thickness (Feet)	Lithology	Approximate Thickness (Feet)	Lithology
Nelway.		Top not exposed.	Grey dolomite containing distinctive black masses with small white spots.				
		500 (?)	Dark blue-grey fine-grained limestone with thin argillaceous beds.				
Gradational contact.							
Laib.	Upper Laib.	3,000	Grey calcareous phyllite, grey brown and green phyllite; thin calcareous lenses.	Top not exposed.	Grey and brown micaceous quartzite; minor green phyllite, black argillite, and limestone.	Top not exposed.	Green and grey phyllite, grey and brown micaceous quartzite, minor limestone lenses.
	Emerald.		Brown-weathering grey siliceous argillite.	200–300	Black calcareous argillite.	500	Black, crenulated calcareous phyllite.
	Reeves.	450	Grey, poorly banded limestone.	350	Interbanded white grey and black crystalline limestone.	130	Banded grey and white limestone.
	Truman.	350	Green phyllite.	100	Brown skarny calcareous argillite.	60	Green and brown phyllite, white limestone.
			Grey-green and brown phyllite, with calcareous lenses most common near the base.		Brown micaceous argillite.		
					Brown argillite with thin calcareous beds.		
					10–20 feet of white crystalline argillaceous limestone.		
Conformable contact.							
Reno.	Upper Reno.	60	Blocky grey quartzite, of which the upper 30 feet contains coarse calcareous quartzite; cross-bedded.	40–50	Blocky grey quartzite with lenses of calcareous quartzite, micaceous quartzite, and minor limestone.	5–10	Blocky grey quartzite.
	Lower Reno.	560	Grey micaceous quartzite and dark-grey to black phyllite.	500	Grey-brown to grey micaceous quartzite with grey blocky beds near the base	230	Dark-grey micaceous quartzite interbedded with dark-grey to black phyllite.
Conformable contact.							
Quartzite Range.	Upper Navada.	250	White quartzite beds as much as 2 feet thick.	135	White quartzite, beds less than 1 foot thick.	35	Thin-bedded white quartzite.
	Lower Navada.	400	Thin-bedded greyish-white quartzite and dark grey-brown micaceous quartzite, some greenish-grey phyllite.	100	Brown micaceous quartzite with greyish-white beds.	100	White grey and brown quartzite interbedded with grey and green phyllite.
						65	Greenish phyllite and grey-brown quartzite.
						20	Interbedded grey and white limestone and greyish-brown phyllite.
						100	Greyish-brown phyllite and quartzite.
	Nugget.	Base not exposed.	Massive white quartzite.	Base not exposed.	Nugget (?) massive white quartzite.	Base not exposed.	Massive white quartzite.

Quartzite Range Formation

The Quartzite Range formation was named by Walker (1934), after the Quartzite Mountain Range now known as the Nelson Range. Mathews (1953) subdivided the formation into three members—the Motherlode, Nugget, and Navada—using names that originated in the gold mines of the Sheep Creek camp. These subdivisions were based on the rock types exposed in the northern part of the Sheep Creek anticline near Sheep Creek, but they may readily be recognized along the anticline to the south and in the lead-zinc Mine Belt to the west. Only the upper two members—the Nugget and the Navada—are exposed within the Mine Belt.

Nugget Member.—The Nugget member was divided into three units by Mathews (1953), but only the upper unit is exposed in the Mine Belt. The Upper Nugget is massive white quartzite. In the southern part of the Sheep Creek anticline it forms bluffs on the western and southern slopes of Lost Mountain, but can be seen more easily on the South Salmo River about 5 miles from the Salmo River (*see* Fig. 3). In the Mine Belt the Upper Nugget is exposed east of the Reeves MacDonald mine in the core of the Salmo River anticline (*see* p. 64). The white quartzite forms bluffs on the south side of the Salmo River canyon and is readily seen on the north side of the river 2,000 feet west of Shenango Canyon. At the latter locality it contains a thick sill-like mass of green phyllitic volcanic rock which is locally amygdaloidal. On the northern slope of Truman Hill white quartzite, possibly belonging to the top of the Upper Nugget, is exposed in the lowest outcrops just south of Lost Creek. Only 20 to 30 feet of white quartzite is exposed in these outcrops, and it is not known whether it is the top of the Nugget or a white bed in the Lower Navada.

In general, the Upper Nugget quartzite is white on both fresh and weathered surfaces, but some weathered surfaces are rusty. Bedding planes are a few feet apart and are marked by joints or very thin micaceous partings. Locally on the Salmo River anticline, parallel joints a few inches apart, and less commonly a poor cleavage, destroy the typical blocky and massive character of the quartzite. On the Sheep Creek anticline, rounded quartz grains as much as 5 millimetres in diameter can readily be seen in the quartzite, but in the Mine Belt, quartz grains are difficult to distinguish. Even the purest white quartzites contain a few flakes of muscovite.

Mathews (1953) gives the thickness of the Upper Nugget in the Sheep Creek camp as ranging from 135 to 375 feet. On the south slope of Lost Mountain, about 10 miles south of the Sheep Creek camp, the Upper Nugget is approximately 600 feet thick. The base of the Upper Nugget is not exposed farther to the southwest nor is it exposed in the Mine Belt, and consequently no other estimate of thickness has been made.

Navada Member.—The Navada member has been subdivided by Mathews (1953) into two parts—a lower part of brown micaceous quartzite and an upper part of white quartzite. These two units can be recognized to the south along the Sheep Creek anticline and in the Mine Belt to the west. In the Mine Belt the Navada member is well exposed on the north slope of Truman Hill, where it forms cliffs along the south side of Lost Creek (*see* Plate IV). North of Lost Creek the quartzite forms a prominent open ridge which runs south from the Jersey townsite to the Lost Creek gravel terrace, and is known locally as the Quartzite Ridge. The Navada member occurs in the core of the Salmo River anticline throughout its length, and to the north on the east and west sides of McCormick Creek. It is well exposed on the banks of the Pend d'Oreille River just below the Reeves MacDonald mine.

The section exposed on the south side of the South Salmo River west of Rainy Creek (*see* Table III) is typical of the Navada member in the southern part of the Sheep Creek anticline. The Lower Navada is dominantly brown and greyish-brown micaceous quartzite with some impure white beds and thin beds of greenish phyllite. The white beds range from a few inches to several feet thick and occur at irregular intervals through the section. The presence of thin micaceous beds near the top of the Nugget and many white beds near the base of the Navada makes the contact between the two members poorly defined. The Lower Navada grades upward into white quartzite of the Upper Navada. In the transition from Lower to Upper Navada, beds of white quartzite about 3 inches wide with ½-inch interbeds of phyllite grade into white quartzite beds about 8 inches thick, with only wisps of phyllite. The Upper Navada quartzite is dominantly white, but locally has a pinkish or a greenish cast. Beds range from a few inches to nearly 2 feet thick. Individual rounded quartz grains as much as a few millimetres in diameter can be readily distinguished and some of the beds show cross-bedding.

To the west, on the north slope of Truman Hill, the Navada member is lithologically very similar to that on the Sheep Creek anticline, but the white quartzites are finer grained and not cross-bedded, and the beds are no more than a foot thick.

On the Salmo River anticline the Lower Navada contains a relatively thin section of green phyllite and impure white limestone that does not occur either on Truman Hill or the Sheep Creek anticline. Because of the complex structure along the Salmo River anticline, the detailed stratigraphy of the Lower Navada is not well known, but the green phyllite occurs near the base. The phyllite is 50 to 75 feet thick and contains lenticular calcareous beds locally as much as several feet thick. The complexity of structure makes it difficult to place the base of the Navada member because interbedded white micaceous quartzite near the contact is repeated by shearing and isoclinal folding.

In the Upper Navada on the Salmo River anticline, bedding and joint planes are a few inches apart. At places, as on the northern slope of Salmo River about 1,500 feet west of Shenango Canyon, well-developed cleavage causes the rock to break into large plates a fraction of an inch thick.

The thickness of the Navada member as measured at three localities is listed in Table III. In the southern part of the Sheep Creek anticline, the thicknesses of the Lower Navada (400 feet) and the Upper Navada (250 feet) are fairly uniform, except on the eastern limb on the southeast slope of Lost Mountain. In this area the Lower Navada is little more than 100 feet thick, probably as a result of structural thinning the exact cause of which is not known. In the northern part of the Sheep Creek anticline, Mathews (1953, p. 18) lists the range in thickness of the Upper Navada as 20 to 160 feet and of the Lower Navada as 100 to 140 feet, considerably less than the thicknesses of these units in the southern part of the anticline. In the section measured on the northern slope of Truman Hill, the Upper Navada is completely exposed, but the Lower Navada may be incomplete at the base. Farther to the north the structure is complicated and exposures are poor, so that estimates of the thickness of either the Upper or Lower Navada cannot be made with certainty. On the Salmo River anticline, the complex structure makes it difficult to determine the thickness of the Navada member. The Upper Navada is well exposed at many places and ranges from 25 to 30 feet thick, but the Lower Navada is complexly folded and sheared, and any measurement of apparent thickness is of little value.

Reno Formation

The type section of the Reno formation near the top of Reno Mountain was first described by Walker (1934, p. 8). It was studied again by Mathews (1953, p. 21) and redefined to include those beds lying between the white quartzite at the top of the Quartzite Range formation and the first calcareous bed at the base of the Laib.* He subdivided the Reno formation into a "quartzitic member above and an argillaceous below." Mathews' definition has been followed in the present study, and the rock types he described can be recognized widely in the Eastern Belt. The writers have used the terms "phyllite" and "micaceous quartzite" for the Lower Reno because these terms are more descriptive of the rock over all the map-area than the terms "argillite" and "argillaceous quartzite" used by Mathews. The Upper Reno proved to be a valuable marker in the Mine Belt and was mapped during the course of the work, but it is no more than a few tens of feet thick and is not shown on the final maps.

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* Little's definition of the Reno (1950, p. 13) had the same intent, but the first calcareous bed at the base of the Laib is 100 to 300 feet below the top of the prominent limestone which Little considered to be the basal member of the Laib group.

The Reno formation is exposed on Lost Mountain on both limbs of the southern part of the Sheep Creek anticline, but it can be seen best near the crest of the anticline south of the South Salmo River. In the Mine Belt, Reno quartzite forms the upper cliffs on the northwest slope of Truman Hill. North of Truman Hill, parts of the Reno formation are exposed in the structurally complex area between the Jersey and Emerald mines, on the north and south sides of Sheep Creek near the H.B. mine, and on the east side of Aspen Creek about a mile north of the H.B. mine. To the south, Reno quartzite occurs on both limbs of the Salmo River anticline and has been found north of the anticline, east and west of McCormick Creek.

The Reno formation is dominantly grey micaceous quartzite. The lower member, between 500 and 600 feet thick, is micaceous and phyllitic. The upper member, a few tens of feet thick, is blocky and contains beds and lenses with relatively coarse quartz grains* set in a calcareous cement. The lower member grades into the upper so that the contact between the members is poorly defined, although the characteristic lithologies are different.

On the Sheep Creek anticline on the south side of the South Salmo River, the base of the Reno quartzite is well defined. Dark-grey to black phyllites containing beds of grey quartzite about a foot thick overlie the Upper Navada white quartzite at the top of the Quartzite Range formation. The basal, phyllitic part of the Reno formation is several tens of feet thick and grades upward into grey to greyish-brown quartzite with minor grey phyllite. Beds in the quartzite are generally an inch to a few inches thick and commonly show cross-bedding. Much of the quartzite is rich in magnetite, and cross-beds are accentuated by lenses of magnetite. Toward the top of the formation, phyllitic partings are absent and the quartzite becomes lighter grey and lacks magnetite. The uppermost beds which form the Upper Reno are coarse grained and invariably cross-bedded. Rounded quartz grains 3 to 5 millimetres in diameter are set in a calcareous cement which weathers out to produce a characteristic pitted surface. These calcareous beds are well displayed on the north side of the South Salmo River between elevations of 3,000 and 3,500 feet at the crest of the Sheep Creek anticline where the slope of the hill is parallel to the plunge. The calcareous quartzite grades upward into the lowest limestone bed in the Laib formation.

On the northwestern slope of Truman Hill, the lowest 100 feet of the Reno formation is made up of brownish-grey micaceous quartzite with a few grey blocky beds ranging from 2 feet to as much as 10 feet thick. These rocks are in relatively sharp contact with the underlying white quartzite at the top of the Quartzite Range formation and grade upward into a uniform section of brownish-grey micaceous quartzite. Micaceous quartzite of the lower member makes up most of the Reno formation on Truman Hill. It grades upward into 40 to 50 feet of grey blocky quartzite forming the Upper Reno. The lower 15 feet of the Upper Reno is mainly grey blocky quartzite, but it contains scattered lenses of calcareous quartzite in which opalescent quartz grains as much as 2 millimetres across stand out on surfaces from which the calcareous cement has been weathered. These rough surfaces contrast with the smooth surfaces of the blocky non-calcareous quartzite. The lower 15 feet of the Upper Reno is overlain by a 3- to 5-foot bed of greyish-white limestone, and this in turn is overlain by 30 feet of micaceous quartzite with a few blocky beds. The thin limestone bed is well displayed on Truman Hill, but it occurs only locally elsewhere, and is considered part of the Reno formation. The quartzite is conformably overlain by an 8- to 10-foot band of limestone at the base of the Laib formation. This limestone band marks the change from the dominantly quartzitic section beneath to the calcareous and argillaceous Laib formation above.

Most of the Reno formation on Truman Hill and to the north near the Jersey and H.B. mines is composed mainly of quartz and biotite. Such biotite-rich rocks have a brownish cast and are rusty on weathered surfaces. Near the Jersey and Emerald stocks the Lower Reno has a mottled appearance on weathered surfaces with oval light brown blotches 1 to 2 inches in larger dimension, surrounded by the darker rusty-coloured rock. The blotches are thought to represent a patchy distribution of biotite. The calcareous part of the Upper Reno is made up of quartz and varying amounts of calcite, garnet, pyroxene, amphibole, and epidote. The silicates give these calcareous rocks a greenish or spotted green and brown colour on fresh surfaces and commonly inhibit the development of the characteristic pitted weathered surface.

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* These rocks are described as grit by Mathews (1953, p. 22).

On the Salmo River anticline the Reno quartzite is mostly a well-cleaved medium- to dark-grey micaceous quartzite with only a few feet of massive grey quartzite of the Upper Reno at the top. The micaceous quartzite, which has a brownish cast on weathered surfaces, is made up of interbedded light-grey quartzite and dark-grey micaceous phyllite in beds commonly less than an inch thick and in places a few inches thick. The Upper Reno is a fine-grained grey blocky quartzite that locally contains opalescent quartz grains large enough to be visible without a hand-lens. In places there are characteristic lenses of calcareous quartzite a few inches thick in which the quartz grains stand out on weathered surfaces.

On the southern part of the Sheep Creek anticline, the total thickness of the Reno formation is fairly uniform and is estimated to be between 600 and 650 feet. This is close to the average thickness of the Reno formation given by Mathews (1953, p. 22) in the Sheep Creek camp and is similar to the thickness measured on Truman Hill and estimated at several places on the Salmo River anticline. The thickness of the Upper Reno ranges from about 125 feet in the northern part (Mathews, 1953, p. 22) and about 60 feet in the southern part of the Sheep Creek anticline to only a few feet on the Salmo River anticline.

Laib Formation

The Reno formation is conformably overlain by a thick assemblage of phyllite, micaceous quartzite, and limestone known as the Laib formation. The term "Laib" was introduced by Little (1950, p. 15) from exposures near the head of Laib Creek about 30 miles northeast of Salmo. The base of the Laib is sharply defined, but the top grades into the lower part of the Nelway formation; the upper contact is difficult to place and probably the contact shown on the map (*see* Fig. 3) does not follow one horizon. Rocks of the Laib formation underlie most of the Mine Belt as well as large areas in the southern part of the Sheep Creek anticline. In the Mine Belt the lower part of the Laib formation has been studied in detail because it contains the lead-zinc orebodies. Three members—the Truman, Reeves, and Emerald members—have been defined in the lower part of the formation. The Upper Laib has not been subdivided because no well-defined markers have been found within it.

Truman Member.—The basal member of the Laib formation is named by the writers the Truman member, from exposures on the northwestern slopes of Truman Hill. Although the grade of metamorphism is moderately high at this locality, the structure is relatively simple and the succession of rock types can be determined. Truman Hill is one of the few localities in the Mine Belt where the Truman member can be measured as a simple succession not repeated by folding. North of Truman Hill the Truman member is widely distributed near the mines as far north as the H.B. and again at the head of Aspen Creek. To the south the Truman member occurs on the flanks of the Salmo River anticline and on subsidiary folds south of the anticline near the Reeves MacDonald mine. It is well exposed on the Pend d'Oreille River just below the mine. In the southern part of the Sheep Creek anticline the Truman is present on Lost Mountain, but can be seen most readily on the north or south slopes of the South Salmo River near the crest of the anticline. In the northern part of the Sheep Creek anticline, the Truman member has been traced from the ridge west of Mount Waldie to the head of Billings Creek and is recognized again on the northern slope of Sheep Creek and near the Reno mine. The

Truman member includes the first, second, and probably fourth members of the Laib group described by Mathews (1953, p. 23).

The Truman member is a moderately thin sequence of phyllite, argillite, and limestone with gradations between these rock types. It separates the Reno quartzite from the relatively thick and uniform Reeves limestone. Where the grade of metamorphism is moderately high, as on Truman Hill and near the mines to the north as well as in the northern part of the Sheep Creek anticline, rocks of the Truman member are interbedded brown argillites, hornfels, skarn, and limestone. Elsewhere in the area the Truman is mainly phyllite or schist with interbands of limestone.

On Truman Hill the base of the Truman member is marked by a bed of limestone 10 to 20 feet thick which grades upward through calcareous argillite into brown argillite with a few calcareous bands. The brown argillite in turn grades upward through calcareous argillite into the Reeves limestone. The basal limestone of the Truman member is white or has a brownish tinge and contains very thin brown micaceous partings. The argillite is thin bedded. Commonly, the calcareous beds weather away, leaving the argillaceous beds standing out on weathered surfaces. The non-calcareous argillite is rusty-weathering and on fresh surfaces is brown, greyish brown, or, rarely, greenish and has a poor cleavage. To the north, near the Jersey and Emerald stocks, the argillite contains clusters of biotite flakes which weather into oval depressions one-quarter to one-half inch in long dimension and give the rocks a spotted appearance. On Truman Hill and near the H.B. mine the calcareous argillite contains minor garnet, epidote, and pyroxene, and near the Jersey and Emerald stocks, skarn and skarny argillite are common. Locally the rocks are silicified and bleached to a light-grey weathering, hard, thinly banded rock made up of very fine-grained quartz and lime silicates.

On the Salmo River anticline the Truman member comprises green and brown schist and phyllite interbanded with white limestone. Because of isoclinal folding and shearing the succession within the member is uncertain, but brownish beds apparently predominate near the base and greenish beds near the top.

In the southern part of the Sheep Creek anticline, the basal limestone of the Truman member is lenticular and only a few feet thick. It grades upward into green and brown poorly foliated phyllite, locally containing thin lenses of argillaceous limestone. The upper 100 feet of the Truman member is green phyllite, in the top 10 feet of which are one or two bands of limestone.

In the northern part of the Sheep Creek anticline, on the western limb of the western anticline (*see* p. 76), the basal limestone bed of the Truman member is thicker and more continuous than it is to the south. Between the crest of the ridge west of Mount Waldie and the head of Billings Creek, it ranges from about 30 to as much as 80 feet thick; near the Reno mine it is between 20 and 40 feet thick. The limestone is white, weathers cream, and contains brown wisps of argillaceous material. It is overlain by grey, greyish-brown, and locally greenish phyllite, with calcareous or skarny beds near the top. Near the Reno mine the non-calcareous part of the Truman member is a rusty-weathering brown micaceous argillite with poor cleavage like that of the type locality on Truman Hill.

The Truman member at the type locality is about 100 feet thick. To the north, on the northern slope of Sheep Creek about 1,500 feet west of the H.B. mill, a relatively simple section of the Truman member is about 80 feet thick. On the Salmo River anticline the simplest sections of the Truman member are 30 to 50 feet thick, but the amount of thickening or thinning caused by deformation is not known. Throughout the Mine Belt, thicknesses of apparently monoclinal successions comprising the Truman member range from a few tens of feet to as much as 200 feet owing to squeezing or to thinning and thickening by minor folds and faults. In the southern part of the Sheep Creek anticline where the structure is simple, the Truman member has a relatively uniform thickness of between 300 and 350 feet. In the northern part of the anticline where the structure is more complicated, the range in thickness is greater, but thicknesses of about 300 feet are common.

Reeves Member.—The Truman member is conformably overlain by the Reeves limestone, so named from exposures of the limestone near the Reeves MacDonald mine. The Reeves member is defined as the calcareous succession between the uppermost argillite or phyllite band of the Truman member and the first argillaceous bed at the base of the overlying Emerald argillite. The boundaries are fairly well defined; only a thin zone of limestone with argillaceous partings separates the Reeves from the underlying Truman member, and only one or two thin bands of limestone occur at the base of the overlying Emerald argillite. The Reeves member is limestone that has been locally altered to dolomite. The Reeves limestone contains all the major lead and zinc deposits of the district.

Typical Reeves limestone is exposed on the Nelway–Waneta road a few hundred feet northwest of the portal of the 1900 level of the Reeves MacDonald mine. This is regarded as the type locality, and the name Reeves has been used despite the fact that folds and faults near the Reeves MacDonald mine complicate the type section. The same limestone has been called the H.B., Jersey, and Emerald limestone at each of these mines. The name Reeves limestone has been used previously (*see* White, 1949, p. 171; Green, 1954, p. 12) and is well known in the district.

The Reeves limestone is exposed intermittently along the south side of the Salmo River anticline from south of the Pend d'Oreille River about 2 miles west of the Reeves MacDonald mine to Shenango Canyon about 3 miles east of the mine. On the north limb of the Salmo River anticline it is exposed almost continuously from near the head of Fraser Creek to the top of the hill about a mile northwest of Shenango Canyon, a distance of about 8 miles. The limestone occurs north of the Salmo River on the west side of McCormick Creek and intermittently for about a mile east of the creek. The Reeves limestone forms bluffs east of the Salmo River on the north and south sides of the South Salmo River, and the lower part of the member caps the top of Truman Hill. North of this area a belt underlain mainly by the Reeves limestone ranges from a few hundred feet to as much as a mile wide and extends as far as the head of Aspen Creek. In the southern part of the Sheep Creek anticline the Reeves limestone occurs on the western and southeastern slopes of Lost Mountain, but is most accessible on the anticline south of the South Salmo River. In the northern part of the Sheep Creek anticline the Reeves limestone has been studied between the ridge west of Mount Waldie and the northern slope of the ridge west of Reno Mountain. It has also been recognized in the central syncline on the southwestern slopes of Mount Waldie.

In the Mine Belt the Reeves limestone is characteristically a banded grey and white or black and white fine- to medium-grained rock. It generally weathers blue-grey, and the banding is more easily seen on fresh than on weathered surfaces. Individual bands are commonly between one-half inch and 4 inches thick, and the black bands are thinner than the white. Bands of grey or white limestone a few feet thick and lacking the finer banding are fairly abundant.

The limestone contains minor amounts of quartz and muscovite, and in places joint surfaces parallel to the banding are coated with mica flakes. Fine needles of tremolite can be found in the limestone northwest of Shenango Canyon, and fine needles as well as coarse rosettes of tremolite are present locally in most of the limestone between the lower part of the South Salmo River and the head of Aspen Creek. Near granitic masses at the Jersey mine and near the head of Aspen Creek the limestone locally is coarsely crystalline and at places contains garnet and pyroxene.

Dolomite in the Reeves limestone weathers buff, is poorly banded or massive, and is generally finer grained than the limestone. Relatively small masses of dolomite surrounding zones of sulphide replacement are commonly banded. Larger masses of dolomite containing only minor amounts of sulphides are found west of the H.B. mine and in the complex folds immediately south of the Salmo River anticline near the Reeves MacDonald mine. At these two localities the dolomite is light grey and massive or very poorly banded. On both sides of the Pend d'Oreille River about 1,000 feet south of the portal of the 1900 level of the Reeves MacDonald mine the dolomite is black, vaguely banded, and siliceous, but similar dolomite has not been seen elsewhere in the Reeves member.

In the southern part of the Sheep Creek anticline the Reeves limestone is a grey fine-grained relatively massive rock. Uniformly dark- or light-grey bands, or less commonly white bands, are a few feet to a few tens of feet thick. Near the base of the limestone and at places throughout the section, buff argillaceous wisps and lenses give a mottled appearance to weathered surfaces. Bedding planes are difficult to see, and the most prominent structure is a lineation produced by the intersection of argillaceous lenses and a poor irregular cleavage. The lineation plunges southward parallel to the axis of the Sheep Creek anticline.

In the northern part of the Sheep Creek anticline west of the Western anticline the Reeves limestone is fine to medium grained, white or grey, and weathers grey or blue-grey. In places it contains rounded dark-grey coarsely crystalline spots one-quarter to three-quarters of an inch in diameter resembling remnants of fossils. The limestone is poorly banded and locally contains thin argillaceous wisps. It can be distinguished with difficulty from the limestone at the base of the Truman member, which, west of the Sheep Creek camp, is thick and well exposed. The Truman limestone is buff, grey, or white and is argillaceous, whereas the Reeves is blue-grey, grey, or locally white and contains little or no argillaceous material.

The Reeves limestone in the southern part of the Sheep Creek anticline is between 400 and 450 feet thick. In the northern part of the anticline it ranges from about 100 feet west of the Reno mine to somewhat more than 500 feet thick on the lower western slopes of Mount Waldie between Bennett and Billings Creeks. In the Mine Belt complete sections of the Reeves limestone are found only on the overturned limbs of folds where the limestone might be expected to be abnormally thin. Near the Emerald mine in this position the limestone is between 300 and 350 feet thick. At most places on the overturned limb of the Salmo River anticline the limestone is between 200 and 500 feet thick, but locally it is thinner or thicker; the section listed in Table III is abnormally thin.

Emerald Member.—The Emerald member is named from exposures near the Emerald mine and is defined as the black argillite conformably overlying the Reeves limestone. The base of the argillite is sharply defined and is well exposed in several places in the Mine Belt. The Emerald member grades upward into green and brown phyllite of the Upper Laib, so that the upper contact is difficult to place. Throughout the Mine Belt the Emerald argillite has been found mainly on the overturned limbs of folds. Near the Emerald mine it occurs on the western limb of the Jersey anticline where the rocks dip eastward and face westward. It has been traced from the mine south to near the mouth of the South Salmo River. It extends north from the Emerald mine and is exposed intermittently in an overturned position from the south slope of Sheep Creek as far north as the head of Aspen Creek. In the Salmo River anticline, on the overturned northern limb, the Emerald argillite has been followed from the east side of Wallack Creek to the head of Fraser Creek. It can be seen readily on the Pend d'Oreille River about 1,000 feet south of the Salmo River. Near the Reeves MacDonald mine the argillite occurs on the south side of the Salmo River anticline and forms the hangingwall of the mineralized limestone. North of the Salmo River canyon, black phyllite, probably belonging to the Emerald member, outcrops along McCormick Creek between elevations of 2,400 and 3,000 feet. It can be traced for about half a mile east of the creek and west almost to the Pend d'Oreille River. The Emerald member has not been identified on the Sheep Creek anticline. The rocks immediately overlying the Reeves limestone in this area do not differ sufficiently from rocks of the Upper Laib to be distinguished as a separate member.

The Emerald member is made up of black argillaceous rocks referred to as either phyllite or argillite. Rocks termed argillite are blocky, have a poor cleavage, and grade into phyllite on the one hand and hornfels on the other. Those termed phyllite have many shiny foliation planes and grade into black schist. Most of the phyllites are crenulated, but some are slaty. At the Emerald mine the argillite is blocky, siliceous, and on weathered surfaces is mottled grey and black. The mottling is caused by partial bleaching, silicifaction, and silication which affects the argillite within a few thousand feet of the Emerald stock. North and south of this zone of metamorphism the argillite is blocky but is not mottled. On the northern slope of Sheep Creek west of the H.B. mine, and on the eastern side of Aspen Creek north of the mine, the Emerald argillite has a more or less well-developed foliation, but at the head of Aspen Creek near the Hidden Creek stock the Emerald member is a grey blocky hornfels. On the overturned limb of the Salmo River anticline the Emerald member is a black phyllite, on the right-side-up limb at the Reeves MacDonald mine it is irregularly crenulated and is referred to as a schist. In the area north of the Salmo River anticline, east and west of McCormick Creek, the black argillite is poorly foliated and locally blocky but commonly shows a pronounced lineation plunging steeply southwestward.

On the Sheep Creek anticline the rocks immediately overlying the Reeves limestone are not black argillite and consequently have been mapped as part of the Upper Laib formation rather than as the Emerald member. In the southern part of the anticline grey and purplish-grey, brown-weathering siliceous argillite with a few limestone bands overlies the Reeves limestone and grades upward into phyllite of the Upper Laib. In the northern part near the head of Billings Creek and west of the Reno mine, grey micaceous phyllite, rusty and locally spotted on weathered surfaces, overlies the Reeves limestone. These rocks are in a zone of relatively high-grade metamorphism and have not been differentiated from the Upper Laib. Absence of the Emerald argillite on the Sheep Creek anticline is thought to signify sedimentary facies changes or non-deposition of the black argillite in this area.

The thickness of the Emerald argillite in the Mine Belt ranges from less than 100 to a few hundred feet. At and northwest of the Emerald mine and near the H.B. the argillite is between 200 and 300 feet thick. South of the Emerald mine on the bluffs east of the Salmo River the Emerald member is 75 to 100 feet thick. In the Salmo River canyon it is about 125 feet thick. The thickness of 500 feet given in Table III is abnormally large.

Upper Laib.—The upper part of the Laib formation comprises a relatively thick sequence of phyllite and micaceous quartzite with minor lenses of argillaceous limestone. It has not been subdivided and is referred to merely as the Upper Laib formation because no well-defined markers have been found within it. Complete sections of the Upper Laib occur in the southern part of the Sheep Creek anticline. The Emerald member has not been recognized in this area, and the base of the Upper Laib is placed at the top of the Reeves limestone. This lower contact is well defined, but the upper contact with the overlying Nelway limestone is gradational. In the Mine Belt the Upper Laib formation overlies and grades downward into black phyllite and argillite of the Emerald member. The top of the Laib formation is not exposed in the Mine Belt.

Rocks of the Upper Laib underlie most of the western and northwestern side of the Mine Belt* and large parts of the Eastern Belt. In the Mine Belt the rocks can be seen readily west of the Emerald mine and along the Pend d'Oreille River near the mouth of the Salmo. In the Eastern Belt the Upper Laib formation forms wide areas of poor outcrop on both sides of the Sheep Creek anticline. The best exposures and most complete sections are on the north and south sides of the South Salmo River about 3 miles from its junction with the Salmo River (*see* Fig. 3).

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* These rocks along the western and northwestern side of the Mine Belt have previously been mapped as the Reno formation (*see* Little, 1950, Map 50-19A; Walker, 1934, Map 299A), but are now known to be highly deformed equivalents of the Upper Laib formation.

In the southern part of the Sheep Creek anticline the Reeves limestone is overlain by a brown-weathering grey and purplish-grey siliceous argillite with a few bands of grey limestone 2 to 3 feet thick. Within 50 or 100 feet of the top of the Reeves limestone the siliceous argillite grades into green, brown, and locally grey phyllite, which is abundant in the lower part of the Upper Laib formation. The phyllite contains thin lenses of grey-weathering buff or white argillaceous limestone, some of which has rounded or oval knots of coarsely crystalline calcite resembling remains of fossils. The green and brown phyllite grades upward into grey and black phyllite, which becomes more and more calcareous to the base of the Nelway formation. The lowest part of the Nelway contains distinctive dark blue-grey limestone with brown-weathering argillaceous partings, and the lowest extensive bed of this type of rock is regarded as the base of the Nelway formation. The contact is gradational and probably has not been mapped everywhere at the same horizon. On the crest and eastern limb of the southern part of the Sheep Creek anticline the phyllites are poorly cleaved and resemble strongly fissile shales. On the western limb they have a stronger cleavage and in places break into micaceous plates a fraction of an inch thick and many inches across. Commonly the phyllites on the western limb display more than one planar structure, which leads to the development of lineation and rod-like rock fragments. The rocks in the northern part of the Sheep Creek anticline are in a zone of higher-grade metamorphism than those in the southern part, and include phyllitic micaceous quartzite, brown argillite, and skarn. The micaceous quartzite is grey to brown, and commonly the rusty weathered surface has small rounded pits or spots where clusters of biotite or other metamorphic silicates have weathered away.

The Upper Laib formation in the Mine Belt is mainly phyllite, schist, and micaceous quartzite. The rocks are highly folded, sheared, and locally thermally metamorphosed and granitized. West of the Emerald and H.B. mines the rocks are grey, black, and green phyllite and greyish-brown, more or less micaceous quartzite. Lenses of argillaceous limestone locally altered to skarn occur within the formation at widely separated points. North of Sheep Creek and west of Woodchuck Cheek thin beds of blue-grey limestone associated with black phyllite occur in rocks that resemble the top of the Laib or the base of the Nelway formation. They are cut off on the west by a fault, and too small a section is exposed to be certain of their correlation. In the southern part of the Mine Belt, between Wallack Creek and the Pend d'Oreille River, rocks of the Upper Laib formation are mainly phyllite and schist coloured dull green, brown, and grey. Locally, brownish quartzitic beds and lenses of blue-grey limestone are present. Some of the grey phyllites are calcareous, but the sequence in general is not calcareous. Most of the rocks are well foliated and display complex attenuated minor folds and less commonly a pronounced lineation. Similar rocks continue to the west on the north side of the Pend d'Oreille River as far as the ridge west of Tillicum Creek and on the south side of the river as far as Church Creek. Some general rock units can be traced into this western area from the area between Wallack Creek and the Pend d'Oreille River, but no well-defined markers have been found.

The Upper Laib formation is of the order of 3,000 feet thick on the crest and eastern limb of the Sheep Creek anticline south of the South Salmo River. In the northern part of the Sheep Creek anticline and in the Mine Belt the thickness cannot be estimated because the top of the Laib formation is not exposed and complexities of the structure are not known. Judging from the area of outcrop and the regional structure, a thickness for the Upper Laib of a few thousand feet is probable for all the map-area.

Nelway Formation

The Laib formation is conformably overlain by the thick calcareous Nelway formation. The term "Nelway" was introduced by Little (1950, p. 18) as a Canadian name for the Metaline limestone of northern Washington that is exposed near the border-crossing point of Nelway. In the map-area the Nelway formation occurs only in the southern part of the Eastern Belt. The formation is divided into a lower limestone, a middle dolomite, and an upper limestone.

North and northwest of Nelway the lower and middle members are well exposed, although the sequence is complicated. On the east side of Rosebud Lake the lower and part of the middle member are exposed in a sequence in which the beds dip eastward and face westward. The simplest and most complete section of the Nelway formation is on the crest and eastern limb of the Sheep Creek anticline between the International Boundary and the South Salmo River. The middle and upper members underlie most of the area east of Russian Creek between the International Boundary and the Pend d'Oreille River.

The lower member of the Nelway formation is dark blue-grey fine-grained limestone and argillaceous limestone. Typically, the argillaceous limestone is made up of calcareous beds a few inches thick alternating with brown-weathering argillaceous beds a fraction of an inch thick. The lower part of the member is more argillaceous than the upper, and near the base beds of argillaceous limestone several feet thick alternate with beds of calcareous phyllite of about the same thickness. The base of the formation, taken as the base of the lowest extensive bed of argillaceous limestone, is difficult to place because of the almost complete gradation between the Nelway and the top of the Laib formation. The upper part of the lower member locally contains rounded knots of relatively coarse calcite as much as an inch in diameter. Many knots show a vague concentric structure and resemble those described by Park and Cannon (1943, p. 19) as algæ.

The middle member of the Nelway formation is fine-grained dolomite, either massive light grey or dark grey, or interbanded light grey and black. Individual layers in the banded dolomite are commonly several inches thick and less commonly a few feet thick. Black layers at many places contain white spots of dolomite generally less than half an inch in diameter. The black layers are discontinuous, with abrupt angular terminations. The origin of the layering is uncertain, but it lies parallel to formational boundaries and is regarded as bedding or as being genetically related to bedding. At many places, dolomite of the middle member is siliceous, and on the eastern limb of the Sheep Creek anticline north and south of the South Salmo River rounded nodules of chert, locally making up more than half the rock, weather out to form a pebbly surface.

The upper member of the Nelway formation is found at only two localities in the map-area and is better known south of the International Boundary. South of the boundary it is typically a fine-grained grey massive limestone, but at places it is dolomitized and at others has a pronounced banding which is regarded as a product of deformation. Thinly banded black and white limestone, somewhat like the Reeves limestone in the Mine Belt, overlies the middle dolomite member of the Nelway formation on the eastern side of Russian Creek between the Pend d'Oreille River and the International Boundary. This limestone has been traced southward across the boundary and found to be equivalent to the upper grey massive Metaline limestone.

On the eastern limb of the Sheep Creek anticline the Nelway formation is overlain by Active argillite, but no characteristic upper Nelway limestone is present. The contact between the formations has been regarded previously as faulted (*see* Little, 1950), but the evidence is inconclusive, and recent work south of the boundary by Dings (1956) has shown that it is probably a normal stratigraphic contact. It is concluded that the upper Nelway limestone in this area has been dolomitized and is indistinguishable from the middle dolomite.

The origin of the dolomite has not been studied specifically in this investigation, but, in addition to the evidence of dolomitization of the upper member referred to in the preceding paragraph, other evidence of dolomitization of limestone was found in studying the relations between the lower and middle members. The contact of the middle dolomite with the underlying limestone generally is well defined and in single outcrops appears to be parallel to the beds. The irregularity of the trace of the contact, however, especially on the crest of the Sheep Creek anticline near the head of Rainy Creek, where the structure is simple, is taken as evidence that the limestone-dolomite contact transgresses the beds. The contact shown on Figure 3 should not be regarded as a stratigraphic horizon. In the area northwest of Nelway the relationship between limestone typical of the lower member and of dolomite of the middle member is complex—lenses of limestone occur high in the dolomite member and dolomite is found within the lower limestone. Some of the complex distribution of limestone and dolomite in this area may be related to structure, but a satisfactory structural explanation is not apparent (*see* p. 78), and it is concluded that the complex pattern results mainly from the vagaries of dolomitization.

Thicknesses of the members of the Nelway formation are difficult to estimate because of the dolomitization and because the structure is not well known. In most of the area underlain by the Nelway formation the structure appears simple and the dips are mostly gentle. However, much of the formation is massive, and markers within the members have not been recognized, so that little evidence of internal structure is available. Thicknesses have been estimated on the assumption that the structure is relatively simple. On the hills east of Rosebud Lake the lower limestone member is between 600 and 1,000 feet thick. On the Sheep Creek anticline east of Rainy Creek it is estimated to be 500 feet thick, but on the eastern limb of the anticline on the north side of the South Salmo River the apparent thickness is about 800 feet. The middle and upper members in this locality together are between 4,000 and 4,500 feet thick, but the two members cannot be recognized individually. The top of the middle member is exposed about 8,000 feet west of Nelway, 1,500 to 2,000 feet south of the International Boundary. The base of the member to the north is uncertain because of the complex dolomite-limestone distribution, but 3,000 to 4,000 feet of dolomite lies between the top of the middle member and the first underlying limestone lens on the ridge north of Lomond Creek. Park and Cannon (1943, p. 18) give 1,200 feet as the thickness of the middle Metaline dolomite east of Metaline Falls, Washington, but recent work in the Metaline quadrangle has shown that at many places the middle dolomite is 3,500 to 3,800 feet thick, and that the formation totals about 5,000 feet thick (Dings, personal communication). On the south side of the Pend d'Oreille River east of Russian Creek the upper member is about 500 feet thick, and hence the Nelway formation is estimated to be 4,500 to 5,000 feet in total thickness.

CAMBRIAN ROCKS OF THE PORCUPINE CREEK AREA

The preceding descriptions have been of rocks between the International Boundary and the Hidden Creek stock and a related granitized area east of the stock. Similar rocks occur north of the stock, on both sides of Porcupine Creek, but descriptions of these rocks have not been included in the foregoing discussion because positive correlation of all the units across the Hidden Creek stock has not been possible. Structural complexity, accompanied locally by granitization, has made recognition of stratigraphic units difficult or impossible in much of the area, but many of the rocks can be satisfactorily correlated with the Quartzite Range, Reno, and Laib formations, and there is little doubt that the majority of the rocks in the northern area belong to these formations.

In the Porcupine Creek area the Mine Belt crosses Porcupine Creek immediately west of the mouth of Active Creek (*see* Fig. 2) and contains the Jack Pot and Oxide properties. It is bounded on the east by black argillite of the Active formation and on the west by Mesozoic rocks of the Ymir group. The eastern margin of the belt is a well-defined fault; the western is a zone of extremely complex structure in which no well-defined fault has been recognized. A northern limit of the Mine Belt has not been established, but the abundance of granite and lack of mining activity makes the term of little value far north of Porcupine Creek. Detailed studies have been made near the Jack Pot and Oxide properties, and mapping has been carried on for more than a mile west of the properties, east to the Porcupine Creek stock, and north to the head of Last Chance Valley (*see* Fig. 3, sheet C).

In the Porcupine Creek area the most complete section of rocks of the Quartzite Range, Reno, and Laib formations is on the lower slopes south of Porcupine Creek between 2,000 and 4,000 feet west of Active Creek. The rocks in this section dip steeply eastward, face westward, and are on the overturned western limb of a complex isoclinal anticline known as the Jack Pot anticline. White quartzite of the Upper Nugget forms the core of the anticline, west of which the Navada member, Reno formation, and the Reeves and Emerald members occur in what appears to be a simple succession. They are repeated east of the white quartzite core in a structurally complex area extending as far east as the Jack Pot road. The anticline has been recognized on both sides of Porcupine Creek, but the structure is more complex and the stratigraphic section less complete on the north than it is on the south side of the creek.

Structural complexities, many of which are not well known, make stratigraphic correlations with rocks south of the Hidden Creek stock difficult. Many contacts do not follow formation boundaries and are regarded as faults. Normal stratigraphic successions of more than two members are uncommon. In the following, rocks that can be correlated satisfactorily with the Quartzite Range, Reno, and Laib formations are described; other rocks in the Porcupine Creek area are described on pages 38 to 41.

Quartzite Range Formation

The Navada and part of the Upper Nugget member of the Quartzite Range formation are well exposed on both sides of Porcupine Creek in the Jack Pot anticline. The Upper Nugget at the core of the anticline is blocky white quartzite with widely spaced joint planes, and is easily distinguished from other, less pure white quartzites in the area.

The Navada member is best exposed on the overturned west limb of the Jack Pot anticline on the slope south of Porcupine Creek. On this slope, between elevations of 3,200 and 3,700 feet, it can be divided readily into an upper section of white quartzite and a lower section of phyllitic quartzite. The Upper Navada comprises 100 feet of white quartzite with very minor phyllitic partings. The Lower Navada is grey phyllite and quartzite with a few beds of white quartzite. The boundary between the Upper and Lower Navada is sharp, as is the contact with the underlying Nugget and the overlying Reno.

On the eastern limb of the Jack Pot anticline south of Porcupine Creek, Upper Navada white quartzite has been traced from an elevation of 3,900 feet to 4,400 feet on the ridge west of the Jack Pot road. It is more than 150 feet thick and is overlain to the east by typical quartzite of the Reno formation and underlain to the west by a complex sequence of white quartzite and phyllitic grey and brownish-grey quartzite. This complex sequence involves Upper Navada and Upper Nugget rocks and is more than 1,000 feet thick, but has probably been thickened by isoclinal folding and by faulting. A thin lens of limestone, exposed at an elevation of 3,300 feet about 700 feet west of the Upper Navada, and some grey quartzite could be infolds or fault slices of the Laib and Reno formations, but structural evidence is lacking. Lenses of limestone are found in the Lower Navada near the Reeves MacDonald mine (*see* p. 21), and the entire sequence between the Upper Navada and the Upper Nugget on the Jack Pot anticline has been mapped as Lower Navada (*see* Fig. 3, sheet C).

Reno Formation

No complete section of the Reno formation is known in the Porcupine Creek area, but partial sections can be recognized in several localities. At an elevation of 3,300 feet on the overturned limb of the Jack Pot anticline a section of grey to black phyllite and quartzite lies between Upper Navada white quartzite and the base of the Reeves limestone. The section is somewhat less than 100 feet thick and probably represents the lower part of the Reno formation. Rocks of the Upper Reno and Truman member have not been recognized and are probably cut out by a bedding fault that follows the eastern side of the Reeves limestone in this area.

The lowest 100 feet of the Reno is exposed at two switchbacks on the Jack Pot road at elevations of about 3,900 and 4,200 feet. The rocks are dark-grey phyllitic quartzite, overlying the Upper Navada white quartzite to the west and in fault contact with the Reeves limestone to the east.

The Upper Reno formation has been recognized in the Jack Pot 4100 and 4400 adits, at several places on the Jack Pot road between elevations of 3,900 and 4,800 feet, and in a number of diamond-drill holes. The Upper Reno comprises a few tens of feet of grey massive quartzite underlain by brown micaceous quartzite. The quartzite is very fine grained, and only locally in the massive rocks can individual quartz grains be distinguished. No lenses of calcareous quartzite, so typical of the Upper Reno to the south (*see* p. 22), have been seen, but in some sections of drill core and on clean surface exposures, lenses with relatively coarse quartz grains are seen to contain also green metamorphic silicates; such rocks may have been calcareous quartzites before metamorphism.

Laib Formation

The Truman, Reeves, and Emerald members of the Laib formation have been recognized at several places in the Porcupine Creek area, but no simple, complete section of these members has been found. An overturned band of Reeves limestone crosses Porcupine Creek about 500 feet west of Active Creek (*see* Fig. 3). It is overlain by Emerald argillite to the west and is in fault contact with Reno and Navada quartzite to the east. The Reeves limestone explored by the Jack Pot 4000 and 4400 adits is a synclinal remnant conformably underlain by the Truman member and the Reno quartzite. The overlying Emerald member is not exposed in the trough of the syncline. On top of the Jack Pot Hill above an elevation of 5,400 feet, rocks similar to the Truman, Reeves, and Emerald members occur in a granitized area of such complexity that positive correlations are impossible.

Truman Member.—On the south side of Porcupine Creek the Truman member is exposed in the Jack Pot 4000 and 4400 adits and at various places along the Jack Pot road. The Truman is best exposed in the 4400 adit between 230 feet and 410 feet west of the portal. It comprises white limestone and a brown, poorly foliated biotite-rich rock partly altered to greenish skarn. The rocks are termed brown argillite or skarny argillite and closely resemble rocks of the Truman member at the Emerald and Jersey mines. Much of the white limestone has a brownish cast or contains narrow micaceous bands of brown mica. In the 4400 adit the Truman member overlies blocky grey quartzite of the Upper Reno and is overlain to the west by grey and white banded Reeves limestone. Its thickness measured on surface, underground, and in diamond-drill holes ranges from 20 feet to more than 100 feet. The member has been recognized on the north side of Porcupine Creek between elevations of 3,300 and 3,400 feet, about 1,000 feet north of the mouth of Active Creek. In this area a few small outcrops show interbanded greenish-grey phyllite and white limestone which lie between grey quartzite resembling the top of the Reno formation and limestone probably belonging to the Reeves member.

Reeves Member.—A band of Reeves limestone crosses Porcupine Creek about 500 feet west of the mouth of Active Creek and has been traced for 4,000 feet north and 2,500 feet south of Porcupine Creek. On the west the limestone is in contact with black phyllite similar to that of the Emerald member. On the east the limestone crosses at an acute angle beds of a quartzite sequence, and the eastern contact is regarded as a fault. The limestone is medium grained, weathers blue-grey, and on fresh surfaces is thinly banded grey and white. It closely resembles the Reeves limestone in the Mine Belt south of the Hidden Creek stock. The limestone in this band dips eastward and faces westward.

The limestone explored by the Jack Pot 4100 and 4400 levels is also part of the Reeves member. The rock is medium grained, well-banded grey or black and white. In the mineralized area it is poorly banded, buff-weathering dolomite. The limestone occupies an isoclinal syncline and thickens from a few feet at an elevation of 3,900 feet on the

Jack Pot switchback road near the trough to several hundred feet at an elevation of 5,000 feet.

Above about 5,400 feet elevation on the Jack Pot ridge, limestone and dolomite are found which probably represent the Reeves member, but structural complexities and an abundance of granitized rocks make correlation uncertain (*see* p. 123). The limestone is medium to coarse grained, weathers white or blue-grey, and is more or less well banded. Poorly banded dolomite occurs near zones of sulphide mineralization, and quartz and metamorphic silicates occur locally in both the limestone and dolomite.

North of Porcupine Creek, banded limestone is exposed east of the Oxide road between an elevation of 4,400 feet and the crest of the ridge. The limestone overlies quartzite and phyllite resembling rocks of the Navada member and underlies the Active black argillite. The limestone is a grey-banded rock locally siliceous and dolomitic. It resembles the Reeves limestone, except where it contains black argillaceous wisps and bands. In these localities it more closely resembles grey limestone of the Active formation. The structural relationships are complex, and definite correlation of this limestone with the Reeves or part of the Active formation has not been possible (*see* p. 37).

Emerald Member.—Black phyllite of the Emerald member overlies the Reeves limestone on the overturned western limb of the Jack Pot anticline. The phyllite has been traced from Porcupine Creek, 2,000 feet southwest of the mouth of Active Creek, to an elevation of 3,200 feet on the south side of the creek and between 3,400 and 4,700 feet on the north side of Porcupine Creek. The eastern contact with the Reeves limestone is well defined, but the position of the western contact is uncertain. The phyllite is black to grey with many crenulated shiny foliation planes. It is commonly calcareous and on the north side of Porcupine Creek contains two "tails" of limestone regarded as isoclinal infolds of part of the Reeves member. Locally the black phyllite contains lenses of green and brown phyllite, but the green and brown phyllites and phyllitic quartzites typical of the Upper Laib (*see* p. 28) have not been recognized to the west. Rocks between the Reeves limestone on the overturned limb of the antcline and the massive white quartzites 1,000 to 2,000 feet west of the limestone are dominantly black. On the west they are less well foliated than near the limestone and locally contain porphyroblasts of garnet as much as a centimetre across. In places grey, black, and white well-banded siliceous zones occur in the phyllite, and one of these, ranging from 5 to about 50 feet thick, has been traced for more than 1,000 feet. It is parallel to the foliation of the phyllite but resembles a silicified zone rather than a quartzitic bed.

ACTIVE FORMATION

The Active formation was named by Little (1950, p. 21) from its occurrence on Active Creek, a tributary of Porcupine Creek. The formation is predominantly black argillite and slate but contains calcareous members. The rocks are highly deformed and little is known of their stratigraphy. The formation is bounded by faults, and consequently the stratigraphic relationships of the Active to older and younger formations are not seen in the map-area. The Active formation underlies all of the Black Argillite Belt.

Ordovician graptolites were discovered in the Active formation by Little and Okulitch (*see* Little, 1950, p. 22). No fossils have been found in the Black Argillite Belt south of the Hidden Creek stock, but Ordovician graptolites have been found recently in the Leadpoint quadrangle of northeastern Washington (*see* Yates, 1956) in rocks continuous with those of the Black Argillite Belt. Similar fossils have been known for some time in the Ledbetter slate of the Metaline quadrangle (*see* Park and Cannon, 1943, p. 21). In the Metaline quadrangle, Park and Cannon report that the Ledbetter slate disconformably overlies the Metaline limestone, which is equivalent to the Nelway formation of the Salmo Area. The Ledbetter has an apparent thickness of about 2,500 feet. Recent work by M. G. Dings has shown that the Ledbetter is probably unconformably overlain by Silurian rocks that are lithologically similar to parts of the Ledbetter. Locally within the Black Argillite Belt rocks have been found that are similar to those described by Park and Cannon (1943, p. 22) as Devonian. It is concluded that the Active formation in the map-area includes mainly Ordovician rocks, and possibly also some rocks that are Silurian or Devonian.

Many of the rocks of the Black Argillite Belt have been mapped previously as part of the Laib formation (*see* Little, Map 50-19A; Mathews, 1953), but this correlation finds no support in the present study. Very few rock types in the Black Argillite Belt are similar to those in the Laib formation, and none of the stratigraphic sequence of the Laib formation (*see* p. 23) is found in the Black Argillite Belt. Recognition of the Black Bluff and Argillite faults which bound the Black Argillite Belt has simplified the correlation of rocks in the belt with the Active formation.

The Active formation is dominantly black argillite but includes minor amounts of slate, phyllite, argillaceous limestone, and dolomite. Almost all the rocks are characteristically black or dark grey. The more blocky argillites are generally thinly banded and break along widely spaced cleavage planes parallel to the banding. The rocks are highly deformed, and in many outcrops it is difficult to determine whether banding is original bedding or whether it is a secondary structure related to cleavage. In places, metamorphism has produced blocky rocks in which banding is undoubtedly a secondary feature. In most of the belt the rocks have a more or less well-developed cleavage which is parallel to the banding. Dragfolds are common and involve both cleavage and banding. Locally, minute crenulations of cleavage planes produce a pronounced lineation and may entirely mask the cleavage.

The distribution of the Active formation, which underlies the Black Argillite Belt, is shown in Figure 2. South of the Pend d'Oreille River the formation covers an area about 2 miles wide extending from the hills at the head of Harcourt Creek to Russian Creek in northern Washington (*see* Park and Cannon, 1943). To the east the Black Argillite Belt narrows, and no Active formation is found in the creek 2,000 feet west of Shenango Canyon. The Active argillite outcrops again at Shenango Canyon, and from there north to the Hidden Creek stock underlies an area about 2 miles wide. On Porcupine Creek, north of the Hidden Creek stock, the Active formation outcrops in a belt about 3 miles wide but is cut by the Porcupine Creek stock, which is 2 miles in diameter. In addition to the Active formation exposed in the Black Argillite Belt, a small area of the formation lies across the South Salmo River about 6 miles east of Nelway.

South of the Pend d'Oreille River the Active formation is not well exposed, except along the west fork of Russian Creek and near the heads of Harcourt and Fraser Creeks. In this area it ranges from soft friable phyllite to hard siliceous argillite. The phyllite has crenulated micaceous cleavage planes and resembles near-by exposures of the Emerald member of the Laib formation. Relatively soft black argillite, which is the commonest rock type in the Active formation south of the Pend d'Oreille River, is dull, carbonaceous, and generally non-limy. On top of the ridge south of the head of Harcourt Creek, grey-weathering black limestone is interbedded with black argillite, and near the head of the west fork of Harcourt Creek dark-grey limestone, dolomite, and dolomite breccia have been found between elevations of about 3,700 and 3,900 feet. Some of the dolomite is massive, but most is a sedimentary breccia made up of subparallel tabular fragments of dolomite about half an inch thick and a few inches across in a matrix of dolomite. Such breccias are uncommon, but they occur also on the eastern side of the Black Argillite Belt west of the Sheep Creek camp and in the Metaline quadrangle of Washington (*see* Park and Cannon, 1943, Plate X).

Between the Pend d'Oreille River and Shenango Canyon the most continuous exposures of Active argillite are along the Nelway–Waneta road and in the river banks south of the Reeves MacDonald mine. The rocks in this area include both limy and non-limy argillite and are highly contorted, sheared, and crushed because of complex folding and faulting. A limy unit a few tens of feet thick occurs along the northwest side of the Black Argillite Belt from the Pend d'Oreille River to the crest of the ridge south of the

Prospect adits of the Reeves MacDonald mine. This unit is made up of black argillite and dark-grey weathering black limestone in alternating beds half an inch to a few inches thick. Another limy unit, which contains, in addition to the usual dark-grey rocks, some light-grey limestone and dolomite, has been traced due north from the island near the mouth of Slate Creek to the Nelway–Waneta road. South of Slate Creek the Active formation exposed in the banks of the Pend d'Oreille River is dominantly slate.

East of Shenango Canyon, readily accessible exposures of the Active formation are found in the Black Bluff on the Salmo–Nelway highway and along the road from the Salmo Valley to Rosebud Lake. To the north the formation is exposed at many places in less accessible outcrops. The Active argillite in the Black Bluff near the Black Bluff fault is mostly blocky argillite with a few limy beds. To the northeast, away from the fault, bedding is outlined by pyrite-rich beds, and cleavage cuts across the bedding. Closer to the fault the rocks are strongly sheared, and polished graphitic shear planes are common. About 1,500 feet northwest of Rosebud Lake a band of grey argillaceous limestone has been traced for about 3,000 feet in an area of poor outcrop. Dark- and light-grey banded limestone exposed on the 3,400-foot hill northeast of Rosebud Lake may be a continuation of the same limestone band. Rocks to the north of this limestone are black argillite; those to the south are grey phyllite, somewhat lighter coloured than is normal for rocks of the Active formation.

North of the South Salmo River, rocks of the Active formation differ somewhat from those to the south and west. Cleavage and banding in many of the argillites to the north are more obscure than in similar rocks to the south. Rusty weathered surfaces are more common to the north, possibly because of the presence of disseminated pyrrhotite as well as pyrite. In addition, north of the South Salmo River the argillites are locally altered to biotite hornfels and in some of the limy rocks metamorphic lime silicates are common. In short, rocks north of the South Salmo River show evidence of having been thermally metamorphosed while those to the south do not.

Between Lost Creek and the South Salmo River the Active formation is predominantly black argillite with a few limy beds. One limy unit a few hundred feet thick, consisting of alternating beds of black argillite and dark-grey limestone half an inch to a few inches thick, has been traced from about half a mile east of Truman Hill northeast almost as far as the Lost Creek granite stock. Near the stock the limy beds become silicated, bleached, and silicified to a quartz-pyroxene hornfels superficially resembling a whitish quartzite. A narrow band of dark-grey limestone occurs north of Wilson Creek near the Kontiki drill sites (*see* Fig. 3), and limy argillite has been found elsewhere but not mapped. On the southeast side of the Upper part of Wilson Creek west and north of the United Verde adits, several grey and black quartzitic bands in black argillite are well exposed. In the field the rocks appear as thinly banded black siliceous argillite and grey quartzite, but thin sections reveal that these rocks are hornfels, made up of a fine-grained aggregate of quartz, pyroxene, or amphibole with minor amounts of calcite. A number of bands of hornfels* several tens of feet thick have been traced for about 4,000 feet along the southeast side of Wilson Creek. Similar hornfels occurs on the crest of the ridge and on the steep slope south of Lost Creek.

Between Lost Creek and Sheep Creek the Active formation is mainly typical black argillite with relatively few limy members, except for the area shown on Figure 3 as 9c, which is mainly dolomite. About 1,000 feet west of the top of Nevada Mountain a limestone member in the black argillite crosses the ridge and has been traced about 1,000 feet to the north. The member is a few tens of feet thick and is composed of light- and dark-grey banded crystalline limestone with a few thin beds of black argillite. It has not been traced southward and is not known to outcrop more than about 1,000 feet north of the ridge. Similar limestone occurs on the east side of Bennett Creek between the southwest corner of the Sheep Creek stock and the northern tip of the Lost Creek stock. This limestone, which outcrops as two bands on the limbs of a northward-plunging anticline, is overlain by black argillite and underlain by brown biotite hornfels. About 3,500 feet west of the top of Nevada Mountain a band of interbedded limestone and black argillite crosses the ridge and outcrops intermittently down the southwest slope of Nevada Mountain to the pipe-line north of Lost Creek. This member appears to be about 100 feet thick, but thinly interbedded argillite and limestone show extremely complex minor dragfolds. Near the pipe-line the limestone is locally silicified and silicated. The member has not been traced north of the ridge extending west from Nevada Mountain, but similar rocks have been found on the east side of Annie Rooney Creek and to the north as far as the ridge between Annie Rooney and Sheep Creeks.

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* On *Geol. Surv., Canada,* Map 50-19A, these rocks are shown as part of the Reno formation.

North of Sheep Creek and west of the Sheep Creek stock the Active argillite is very similar to that south of Sheep Creek. Limy members are uncommon, and the rocks comprise a monotonous succession of more or less well-cleaved black argillite. Farther north the rocks become blocky, thinly banded, and more siliceous. On the ridge between Nugget Creek and the west fork of Nugget Creek a band of grey to light-grey mottled siliceous argillite 100 to 150 feet thick has been traced from the creek to the crest of the ridge forming the Sheep Creek-Hidden Creek divide. The rocks of this member appear to be intensely silicified and partly bleached. Much of the black argillite within a few thousand feet of the south side of the Hidden Creek stock is siliceous and is thought to have been silicified. Poor cleavage and thin banding in the siliceous argillite are parallel, and have a uniform attitude over relatively large areas. Locally, remnants of beds appear as highly attenuated folds or disrupted lenses, the axial planes of which are more or less parallel to the more prominent banding. This banding is thought to be a secondary structure resulting from shearing and silicification of the argillite.

On the top and eastern side of the ridge between Billings and Bennett Creeks, on the east side of the Sheep Creek stock and near the head of Nugget Creek, dolomite, dolomite breccia, and limestone are mapped as part of the Active formation (9b on Fig. 3). These rocks are on the eastern side of the Black Argillite Belt and are in fault contact with rocks of the Laib formation to the east. Their relationship to the black argillite on the west is uncertain because the structure is not known and the contacts are not well exposed. However, they are considered part of the Active formation because of their dark-grey and black colour and close association with the black argillite. Dolomite and dolomite breccia are the main rock types. The dolomite is fine grained, dark and light grey, and poorly banded. On the north side of Sheep Creek, east of the Sheep Creek stock, it contains bands and irregular masses of chert and silicates. The dolomite breccia is made up of angular fragments of fine-grained light-coloured dolomite in a dark-grey dolomite matrix. The fragments are tabular, less than an inch thick and a few inches across, and are arranged more or less parallel to each other and to a poor banding. The rock is a typical intraformational breccia and resembles that found in the upper part of Harcourt Creek (*see* p. 34), and that described by Park and Cannon (1943) from the Metaline quadrangle. The dolomite breccia outcrops principally on the top and eastern slope of the ridge between Billings and Bennett Creeks for about 2,000 feet south of the Sheep Creek stock. Dark-grey limestone and black argillite form a band with an outcrop width of a few hundred feet on the western side of the dolomite breccia. On the east side of Billings Creek along the lower part of the Ore Hill road, minor amounts of poorly developed dolomite breccia have been found, but the rocks in this area include also poorly banded grey dolomite, dolomite and limestone with black argillite interbeds, and a few bands of green and brown hornfels. North of Sheep Creek on the east side of the granitic stock, the rocks are mainly dolomite, and only a narrow band of limestone, argillite, and hornfels occurs immediately west of the Reeves limestone. Boulders of dolomite and dolomite breccia are scattered over the drift-covered part of the Nugget Creek basin, and a few outcrops of these rocks occur near the head of Nugget Creek.

North of Hidden Creek the writers studied the Active formation only west of the Porcupine Creek stock, including the area east of Active Creek at an elevation of about

4,000 feet where Little (1950) collected Ordovician fossils. In the Porcupine Creek area the rocks are mostly slaty black argillite which is locally limy or siliceous. One limestone member 200 to 400 feet thick has been traced from Porcupine Creek 8,000 feet south along the east side of Active Creek, but it has not been found north of Porcupine Creek. The limestone is a medium- to dark-grey banded rock with interbedded black argillite near the top and bottom. Another limy member in the Active formation occurs close to the limestone-quartzite sequence of the Mine Belt. It has been traced from an elevation of 4,800 feet on Spot Creek to an elevation of 3,100 feet on Active Creek and is recognized again between elevations of 3,000 feet and about 3,600 feet on the north side of Porcupine Creek. On Spot Creek it consists of grey and white banded limestone and grey mottled dolomite interbedded with black argillite. A section of non-calcareous black argillite approximately 100 feet thick lies between this limestone and dolomite zone and the first member in the Laib formation to the west. On Active Creek and Porcupine Creek the calcareous zone exposed is largely grey dolomite containing black streaks. Similar grey limestone and dolomite with black wisps and streaks occur at elevations of 3,400 and 3,600 feet on the north side of Porcupine Creek. These limy members in the Active formation probably are not all at the same horizon but form parts of a limy zone.

On the ridge north of Porcupine Creek and east of the Oxide road grey banded limestone is overlain by black argillite and underlain by brown and grey phyllitic quartzite (*see* p. 133). The limestone contains some black beds and streaks similar to those just described, and may therefore be part of the Active formation. The relationship between the limestone and the underlying phyllite and phyllitic quartzite which resembles the Lower Navada member of the Quartzite Range formation is uncertain.

The Active formation near the International Boundary east of Lead Creek (*see* Fig. 3, sheet B) is well exposed on the hillside north of the South Salmo River and less well exposed on the slopes south of the river. The Active formation is in contact on the west with cherty dolomite of the Nelway formation and on the east with limestone and phyllite belonging to the upper part of the Laib or lower part of the Nelway formation. The nature of these two contacts was not determined in this area. The western contact is well defined and dips steeply eastward; recent work by Dings (1956) in the Slate Creek area south of the International Boundary has shown that it is a normal stratigraphic contact. The eastern contact cannot be placed with assurance because rocks in the upper part of the Laib formation in this area are very similar to those of the Active formation. In the exposures on the north and south sides of the South Salmo River the Active formation is black argillite with several calcareous members and one lens of grey quartzite. The quartzite is very fine grained, thinly banded, and less than 100 feet thick. It has been traced from the crest northward down the upper slopes of the ridge south of the South Salmo River. The calcareous members are fine-grained dark-grey limestone with black argillite interbeds. Toward the east they are lighter grey and resemble the lowest argillaceous limestones of the Nelway formations.

SEDIMENTARY ROCKS OF THE LOWER PEND D'OREILLE RIVER

The lower part of the Pend d'Oreille River crosses a thick, complexly deformed sequence of phyllite, argillite, quartzite, chert, and limestone of uncertain age. These rocks are in fault contact with Mesozoic volcanic rocks on the north and are bounded on the south and east by phyllites of the Upper Laib formation. They cross the International Boundary to the southwest. The non-calcareous rocks are strongly foliated, and cleavage in general dips south. The area is one in which isoclinal folds and bedding faults are to be expected, but close mapping and the tracing of rock units in the areas of best exposure have not revealed details of the internal structure.

The northwestern limit of rocks regarded as part of the Upper Laib formation has been arbitrarily set at the southeast side of a distinctive quartzitic unit found in the lower part of the valley of Tillicum Creek. Rocks of the Upper Laib are grey, black, and locally green phyllite, and the contact between these rocks and the quartzite unit has been traced from Tillicum Creek southwest across the Pend d'Oreille River to Fraser Creek. The quartzite unit near Tillicum Creek is thinly banded grey, green, and brown micaceous quartzite containing a few small lenses of grey phyllite. In the canyon of the Pend d'Oreille River half a mile west of Tillicum Creek it contains a 15- to 20-foot band of grey platy limestone. Near Fraser Creek the quartzitic unit is a very siliceous grey rock resembling a silicified black phyllite. The quartzitic unit is several hundred feet thick, and is succeeded on the northwest by platy black argillite with interbeds of grey weathering black limestone. This later unit has an outcrop width of almost 1,000 feet, and is followed in turn to the northwest by a band of green chert and green phyllite a few hundred feet thick. The chert is thinly banded green and white, and the phyllite is a somewhat sheared argillaceous or pyroclastic rock. These units can be followed as far west as Fraser Creek. Farther west, outcrops are scarce and the units could not be mapped, though some of the rock types can be recognized at a number of places.

Most of the rocks along the Pend d'Oreille River below the Riverside Placer camp (*see* Fig. 2) are black argillite, slate, and phyllite. Locally they contain beds of grey-weathering black limestone, and near the Waneta fault they have a strong cleavage. A thick band of limestone with black phyllite and argillite above and below it has been traced from the International Boundary near Waneta to the ridge between Limpid and Tillicum Creeks. Near Waneta it occurs as lenses, but between Seven Mile Creek and the ridge west of Tillicum Creek it is a continuous band ranging in outcrop width from about 500 feet to more than 3,000 feet.

The limestone weathers white or light blue-grey and is grey or white on fresh surfaces. It rarely displays bedding or banding. Weathered surfaces have a brecciated appearance because of closely spaced irregular fractures, but fresh surfaces generally are of uniform colour and show no fragmentary appearance. The limestone is commonly siliceous and at places contains buff-weathering dolomitic masses a few tens of feet to a few hundred feet across. Black phyllite and argillite lie on both sides of the limestone, except where the Waneta fault on the north brings the limestone into contact with Mesozoic volcanic rocks. The attitude of the limestone is uncertain, but judging from the trace of its contacts it dips southward, as does the surrounding phyllite, probably more steeply than the thrust fault to the north.

The rocks just described have been correlated previously (Little, 1950) with the Cambrian formations that lie to the east. The non-calcareous rocks closely resemble those of the Upper Laib, and the thick limestone is somewhat similar to parts of the Nelway formation. Rocks of the Upper Laib close to the Reeves and Emerald members can be traced from the area north of the Salmo River canyon as far west as Harcourt and Fraser Creeks. However, no distinctive markers have been found stratigraphically above the Emerald member, and the extent of the Upper Laib is uncertain. The green ribbon chert and green phyllite just described are not typical of the Upper Laib, and the northern contact of the Upper Laib is somewhere southwest of this unit. Bedding faults are common in this area, and though the structure is unknown, it is likely that rocks of the Upper Laib are truncated on the north by a fault. The contact shown on Figure 3, however, has been set arbitrarily along the south side of a quartzitic unit and may or may not be a fault contact.

METAMORPHIC ROCKS OF UNCERTAIN CORRELATION

Near the borders of the Wallack Creek and Hidden Creek stocks the rocks have been granitized and cannot be correlated with certainty with other rocks in the area. Along the west side of the Mine Belt between Porcupine Creek and the ridge north of Oscar Creek, argillites have been intensely silicified and bleached. Correlation of the argillites and silicified rocks with others in the map-area has not been possible. These granitized and silicified rocks of uncertain correlation have been mapped as a unit (*see* Fig. 3, Unit 11) and are described briefly in the following paragraphs.

Granitized Rocks

The southeastern part of the Wallack Creek stock (*see* p. 43) is composed of gneissic granite with many inclusions of incompletely granitized sedimentary rocks. Around the margins of the stock, granitic rocks grade over a distance of a few thousand feet into sedimentary rocks of the Lower Cambrian formations. Many of the rock types can be followed into granitized areas, but direct tracing of beds is made difficult by a scarcity of outcrops. Isolated areas of outcrop between Pete and Atkinson Creeks, on the ridge near the head of Pete Creek, and in the lower part of Swift Creek contain lenses of limestone, thin beds of black argillite, micaceous quartzite, and irregular masses of granitic rock. The limestone is grey and white, medium to coarsely crystalline, and almost certainly belongs to the Reeves or Truman members of the Laib formation. Rocks that were originally micaceous quartzites are changed to rusty-weathering micaceous quartz-feldspar-gneiss or to poorly foliated granite. In general, white quartzites are not as completely granitized as the micaceous quartzite with which they are associated, but they commonly contain sodic plagioclase and more or less muscovite. Rocks that were originally black argillite are grey on weathered surfaces and grade into grey micaceous quartzite. Features that might indicate the structure of these granitized rocks are obliterated, and, in general, the sequence of rock units cannot be matched with stratigraphic sequences in the Lower Cambrian formations. In the lower part of Swift Creek, however, limestone lies above black argillite and beneath granitized micaceous quartzite in a sequence that may be correlated with the Emerald argillite, Reeves limestone, Truman argillite, and part of the Reno quartzite. If this correlation is correct, the rocks are overturned.

Metamorphic and granitized rocks near the Hidden Creek stock have been mapped at the Jack Pot and Aspen properties and in the upper part of Hidden Creek east of the stock. Most of these rocks are probably equivalent to parts of the Lower Cambrian formations, but complex structure and intense metamorphism make positive correlation impossible. Limestones are medium grained to coarsely crystalline and at places are dolomitic or contain lime silicates. Biotite schists and purplish biotite hornfels and skarns which probably are metamorphosed argillites and limy argillites are common. Micaceous and white quartzites are strongly granitized. Near the head of Aspen Creek, coarse breccias consist of rounded and angular fragments of partly granitized sedimentary rocks surrounded by granite. The fragments are several inches across, usually well-banded, and may have a parallel or random orientation. Where the proportion of granitic matrix is low, fragments maintain the regional strike or have a curving fold-like pattern.

In the upper part of Hidden Creek, east of the Hidden Creek stock, a large area is underlain by complexly deformed and metamorphosed white and micaceous quartzite, argillite, and limestone. These rocks are north of the Sheep Creek camp, and members on the west side of the camp have been traced north from near the Reno mine through a series of complex steeply plunging folds into granitized rocks on the southeast side of a drift-filled valley tributary to Hidden Creek. Northwest of this valley individual rock units cannot be recognized, but a belt containing limestone and argillite runs northwest, then north across Hidden Creek along the east side of the granite stock, and then east on the north side of Hidden Creek (*see* Walker, 1934, Map 299A). White and micaceous quartzite with little or no limestone lies northeast of the belt containing limestone and argillite. All the rocks are highly metamorphosed and contain more or less granite. Some bands of limestone have been traced several hundred feet, but they are lenticular, and the most continuous bands follow a complex pattern of steeply plunging folds.

Silicified Rocks along Porcupine Creek

In the Porcupine Creek area, rocks referred to as white quartzite form open bluffs on the south side of Jubilee Mountain and on the ridge north of the Hunter V open pit. They cross Porcupine Creek between 3,000 and 4,000 feet west of Active Creek and are also found north of Jubilee Mountain and Oscar Creek. These rocks resemble those of the upper Nugget member of the Quartzite Range formation, but close studies have led to the conclusion that they are silicified grey and black phyllite. The rocks are mainly blocky white quartzite, with minor grey quartzite and lenses of black phyllite. Although bedding or banding is rarely seen in the quartzite, a vague lineation formed by finely crenulated joint surfaces can be seen in practically every outcrop. The lineation plunges southward at angles between 10 and 30 degrees. Study of thin sections shows that the lineation is parallel to the long axes of recrystallized quartz grains which are separated by microscopic bands of muscovite.

The quartzites are confined to a broad band running parallel to the regional strike of the formations, but they form discontinuous lenses. In bluffs south of Porcupine Creek several masses 50 to 100 feet across are roughly circular in cross-section and appear to have long axes lying parallel to the south-plunging lineation. A large mass of quartzite on the top of Jubilee Mountain continues down the south slope to an elevation of 4,400 feet where the slope steepens and the quartzite ends above black argillite. The shape of this mass appears to be synclinal, but similar quartzite to the south in Porcupine Creek has a general anticlinal form. South of Porcupine Creek a large mass of quartzite on the north-trending ridge north of the Hunter V open pit is underlain by black phyllite at an elevation of 3,600 feet along a contact dipping gently southward. The east and west sides of this mass strike north and dip steeply. The surrounding poorly foliated black argillite and phyllite is very highly contorted near the quartzitic rocks. The foliation is commonly obscured or minutely crenulated so that the rocks have a lineation parallel to that in the adjacent quartzites.

The over-all structure of the quartzite and the surrounding argillaceous rocks is not known, and outlines of the quartzitic masses do not appear to fit any normal structural pattern. They might represent giant boudinage, but this possibility has not been supported by detailed field studies. On the other hand, certain features suggest that the quartzites are silicified zones in the argillaceous rocks. One of the strongest pieces of evidence for this suggestion is that irregular lenses of grey quartzite and black phyllite within the white quartzite resemble incompletely silicified remnants. Every gradation from black phyllite through grey siliceous argillite to white quartzite can be seen, but contacts between white quartzite and black phyllite may be quite sharp.

Thin sections reveal the presence of small garnet porphyroblasts in crenulated carbonaceous and micaceous phyllite. The porphyroblasts are also found in grey siliceous argillite, mainly as shadowy outlines partly replaced by quartz. In thin sections of phyllite and argillite, granular quartz appears to replace the muscovite and carbon of the original rock in coalescing lenses parallel to the foliation. The purest white quartzites are granular, with anhedral quartz grains a tenth to a fifth of a millimetre across, fine flakes of muscovite, and interstitial potash feldspar. Sections cut perpendicular to the lineation show rounded interlocking equidimensional quartz grains, while those cut parallel to the lineation show elongate angular quartz grains.

On the north side of Porcupine Creek, obviously silicified rocks are common both east and west of the main bluffs of white quartzite. To the east, in black phyllite and argillite believed to be part of the Emerald member of the Laib formation, beds a few tens of feet wide and as much as 1,000 feet long, and small irregular masses, are composed of siliceous black argillite that grades irregularly into phyllite and non-siliceous argillite. To the west of the quartzite bluffs large areas are underlain by grey to black siliceous phyllite and argillite. Phyllite grades irregularly into siliceous argillite over relatively short distances. Limestone lenses containing round nodules, veinlets, and bands of white quartz are present at places in the phyllite. In summary, unreplaced remnants of black phyllite, relict porphyroblasts, and obvious signs of both local and widespread silicification lead to the conclusion that the blocky white quartzites are products of silicification of the grey and black phyllites.

Seeman and Ymir Groups

Many of the rocks in the Porcupine Creek area west of the Active formation, as well as the granitized rocks near the head of Hidden Creek, have been mapped as part of the Seeman group by Little (1950) and McAllister (1951). The Seeman group, as mapped, consists of a thick assemblage of quartzite, schist, and limestone occurring on both sides of Porcupine Creek and extending for about 15 miles to the northeast. Along the ridge between Hidden Creek and Active Creek the Seeman group was thought to overlie the Active formation (*see* Little, 1950, p. 24) and hence was regarded as post-Ordovician. On Porcupine Creek the Ymir group lies west of, and was thought to conformably overlie, the Seeman group. In the present study it has been shown (*see* pp. 39, 77) that many of the rocks along Porcupine Creek and in the upper part of Hidden Creek probably belong to parts of the Quartzite Range, Reno, and Laib formations. A brief study of other rocks mapped as the Seeman group along upper Ymir and Seeman Creeks (*see* McAllister, 1951, Map 51-4A) has led the writers to the conclusion that the Seeman group in general consists of metamorphosed and structurally complex sedimentary rocks of uncertain age, but including rocks of the Quartzite Range, Reno, and Laib formation. This designation of rocks of the Seeman group has been used in the recent edition of the Geological Survey of Canada preliminary map of the Nelson area (3-1956), and the name Seeman group has been dropped. Rocks in the upper part of Hidden Creek resemble in general lithology those of the Laib, Reno, and Quartzite Range formations, but distinctive members and sequences can be recognized at very few places. The rocks are granitized and complexly folded, but several units have been traced from the granitized area southeast and east into rocks near the Reno mine (*see* Fig. 3). The contact between the metamorphic rocks of the Hidden Creek Valley and the Active formation on the south side and crest of the ridge between Active and Hidden Creeks was regarded by Little (1950, p. 23) as a conformable contact, but it is not well exposed and is complicated by masses of granite. The nature of the contact is uncertain, but in the writers' opinion the contact may be a fault comparable to the Black Bluff fault farther south.

Rocks referred to as part of the Mesozoic Ymir group by Little (1950, Map 50-19A) and McAllister (1951, Map 51-4A) have been studied on the north and south sides of Porcupine Creek between 1 and 1½ miles west of the Jack Pot and Oxide properties. The rocks are in an area of structural complexity and granitic intrusions, and it has not been possible to establish the stratigraphy and structure or to correlate them with the Ymir group or with other rock units. The rocks lie west of the bluffs of massive white quartzite (*see* p. 40) extending from the ridge north of the Hunter V open pit to the top of Jubilee Mountain. They are mainly grey or black fine-grained sedimentary rocks, more or less silicified or converted to hornfels, and locally contain small lenses of limestone.

MESOZOIC VOLCANIC ROCKS

Much of the northwestern part of the Salmo Area is underlain by volcanic rocks referred to by Little (1950, p. 28) as the Beaver Mountain formation. They are described as andesite and latite flows, agglomerate, augite porphyry, breccia, and tuff, and are considered to be Jurassic or Cretaceous in age. These rocks have not been studied in detail in the course of the present work, and have been seen only close to the Waneta fault. Along the fault zone they are sheared and altered, but a few hundred feet from it they are blocky. The rock types studied are mainly mafic pyroclastics and greenstones of uncertain origin.

Before flooding by the Waneta dam, blocky green pyroclastic rocks and minor tuffaceous grey argillites were well exposed in the lower 2 miles of the canyon of the Pend d'Oreille River. These rocks are mainly blocky green agglomerate with vague angular and rounded fragments ranging from about an inch to 8 inches across in a fine-grained clastic matrix. The fragments are commonly amygdoloidal and the matrix, which is darker green than the fragments, contains hornblende crystals probably of pyroclastic origin. Dull-green crystal tuffs with scattered broken plagioclase crystals as much as a quarter of an inch across are found near the mouth of Cedar Creek. Grey tuffaceous argillite occurs near the Waneta power plant and in the canyon east of the mouth of Cedar Creek. One- to two-inch beds in these rocks contain angular fragments of black argillite as much as an eighth of an inch across. These relatively coarse clastic rocks grade into grey to black blocky argillites in which angular plagioclase crystals can be seen under the microscope. To the east on the north side of the Pend d'Oreille River between Reith and Tillicum Creeks, the volcanic rocks are mainly green agglomerate and blocky greenstones of uncertain origin. North of the Riverside Placer camp, fairly large areas are underlain by rusty carbonate-bearing olive-green phyllite. These rocks are sheared and altered volcanics in the Waneta fault zone, and outcrop over large areas because the fault dips southward somewhat parallel to the slope of the hill (*see* p. 56).

On the west side of the Salmo River, rocks west of the Waneta fault are green agglomerate with vague, scattered angular fragments of mafic volcanic rock in a massive fine-grained clastic matrix. To the south are relatively narrow bands of green siliceous tuff and argillite. On the east side of the Salmo River west of Woodchuck Creek, rocks regarded as part of the volcanic sequence include a variety of altered and sheared volcanic and sedimentary rocks. These rocks, which are cut by granitic masses and by a number of faults, have not been mapped with the volcanic rocks by Walker (1934, *see* Map 299A) or Little (1950, *see* Map 50-19A), and are only tentatively mapped as such in the present study because they are west of the Waneta fault and are not similar to any of the rock units to the east.

INTRUSIVE ROCKS

Intrusive rocks in the map-area include stocks of granite, syenite, and monzonite, and sills, dykes, and irregular masses of felsite, aplite, and lamprophyre. In the present study very little work has been done on the intrusive rocks other than mapping their outlines and giving some consideration to their structural effects and age relationships.

Granitic Rocks

Most of the granitic rocks are regarded traditionally as part of the Nelson intrusions (*see* Little, 1950, p. 30) which, from relationships outside the Salmo Area, are post-Lower Jurassic and pre-Upper Cretaceous in age. Small masses of granite along the lower Pend d'Oreille River are similar to the Sheppard intrusions west of the Columbia River (*see* Little, 1950, p. 31, and 1956), which are probably Tertiary. The largest stocks of the Nelson intrusions in the area studied are crossed by Hidden Creek, Sheep Creek, Lost Creek, and Wallack Creek, and have been named from these creeks. Small masses of granite on Iron Mountain are referred to as the Emerald and Dodger stocks (*see* p. 110).

In the Hidden Creek stock, only the marginal facies have been seen. These include a wide variety of medium-grained granitic rocks ranging from quartz-rich biotite granite to diorite, which, with a greater or smaller proportion of partly granitized sedimentary wallrocks, form a complex marginal zone locally as much as a few thousand feet wide. On the southern part of the Jack Pot property north of the stock, layers of granite or highly granitized quartzite alternate irregularly with less granitized sedimentary rock, and the proportion of granite increases toward the main mass of the stock. Similar relationships are found on the east and south sides of the stock, but the masses of granitic rock are more irregular. Near the Aspen property, granite breccias containing angular fragments of partly granitized sedimentary rocks in a granitic matrix have been described previously (*see* p. 39). Only generalized outlines of the Hidden Creek stock are shown on Figure 3 because at many places there is a complete gradation from granite to sedimentary wallrocks, and at others small irregular masses of granite extend far into the wallrocks. The marginal zone of granitized rocks and breccia is cut by massive dykes of granite containing rare inclusions. They resemble rocks near the interior of the stock and suggest that granitization of sedimentary rocks was followed by intrusion of large parts of the stock and of peripheral dykes.

The regional strike of the wallrocks swings markedly, close to and within the marginal zone of the Hidden Creek stock. On the south side of the stock the strike swings from north through northwest to west toward the stock. Inclusions in the southern part of the marginal zone strike east. On the Jack Pot property north of the stock the change in strike is from south to southeast as the stock is approached. East of the Jack Pot, however, the Active argillite changes strike from south to southwest as the stock is approached. On the east side of the stock, south of Hidden Creek, limestone members which strike west swing abruptly northward near the stock and double back on themselves in a series of steeply plunging folds. The significance of the structural complexity around the Hidden Creek stock is uncertain. Possibly forceful emplacement of the granitic rocks created the contorted zone. A conclusion which is favoured by the writers, however, is that granitic intrusion and granitizing solutions were localized in a zone of steeply plunging folds, and that deformation continued during emplacement of the granite. The massive interior of the stock and peripheral dykes are relatively undeformed and may have been emplaced as late-stage magmatic granite.

The Sheep Creek and Lost Creek stocks have been described by Mathews (1953, p. 24). The only observation made here is that wallrocks near the Sheep Creek stock are contorted, whereas those near the Lost Creek stock, though regionally folded, are not contorted.

The southeastern part of the Wallack Creek stock includes a complex mass of granite and granitized sedimentary rocks. Rocks of the Quartzite Range, Reno, and Laib formations along the Salmo River canyon can be traced northeast across the lower parts of McCormick and Wallack Creeks, but farther to the northeast they become progressively more granitized. Though the tracing of units is hampered by a scarcity of outcrops, lenses of limestone can be found along the line of projection of the Reeves limestone on the overturned limb of the Salmo River anticline in areas in which the quartzitic rocks are quartz-feldspar-biotite gneiss. Northwest of these limestone lenses the proportion of granite is higher, but the granite is gneissic and contains lenses of the sedimentary rocks, which in general maintain a northeasterly strike of both the foliation and the long axis of the lenses.

Granitic rocks along the lower Pend d'Oreille River are mainly light-coloured medium-grained granite and syenite. The rocks are highly fractured, and weathered surfaces are white or rust stained but fresh surfaces are light grey. Small rounded or angular amphibolitic inclusions are fairly common. Specimens studied in thin section contain mainly albite and microcline-microperthite with minor amounts of quartz and rare pyroxene or hornblende. Disseminated pyrite gives the common rusty-weathered surface. These granitic rocks intrude black argillite as large or small sills, dykes, or irregular masses. The smaller bodies exposed along the river have very complex shapes and are in sharp contact with irregularly contorted argillite. The southern contact of the large granitic mass between Reith and Seven Mile Creeks is concordant with the foliation of the argillite, and the scattered outcrops north of the river may be parts of a large sill-like mass dipping gently south.

Felsite

Sills and dykes of felsite or quartz feldspar porphyry are common at places in the map-area. They are characteristically white-weathering aphanitic rocks resembling massive chert, but less commonly are porphyritic or very fine grained. Because of their white-weathered surfaces and resistance to erosion, they stand out among the brown and black phyllites and argillites which they commonly intrude. Coatings of iron oxides from the weathering of disseminated pyrite make the study of hand specimens difficult. Under the microscope the felsitic rocks are seen to be composed of quartz, plagioclase, and potash feldspar in anhedral grains about a tenth of a millimetre across. Fine flakes of biotite or muscovite as well as accessory pyrite, magnetite, and garnet are present in some sections. In one specimen the quartz and potash feldspar have a granophyric texture. Porphyritic rocks contain phenocrysts of quartz, microcline-microperthite, or andesine.

Masses of felsite are most commonly parallel to the strike of the foliation of the enclosing rock and are therefore referred to as sills. They are generally steeply dipping and may or may not be parallel to the dip of the foliation in the wallrocks. The sills range from a few feet to more than a hundred feet wide and extend for thousands of feet along strike. They are most common in rocks of the Upper Laib formation along the east side of the Salmo Valley between the South Salmo River and the head of Woodchuck Creek and between McCormick Creek and the Pend d'Oreille River. They are also fairly numerous in the Active argillite east of the Jersey and H.B. mines. In the Sheep Creek mining camp a swarm of quartz porphyry sills of the same general appearance and composition as the felsites and aplites to the west extends through most of the camp. The sills are fully described by Mathews (1953, p. 26). The only similar dyke in the southern part of the Sheep Creek anticline is south of the South Salmo River. It forms a prominent line of outcrops more than 3,000 feet long running southwestward about 2,000 feet southeast of Rainy Creek. The dyke is discontinuous, but at places is as much as 200 feet thick. North of the South Salmo River continuity of the dyke has not been established, but intermittent outcrops of felsite essentially on strike from the dyke near Rainy Creek occur near the South Salmo road and north of it.

Augite-biotite Monzonite

Three similar stocks of augite-biotite monzonite lie within the map-area, and others have been described from the Ymir area to the north (*see* McAllister, 1951, p. 31). One stock on the ridge between the Emerald mine and the Salmo River referred to as the Salmo River monzonite was described by Daly in 1912 (p. 304). A second lies about 2 miles northeast of the Emerald mine, and the third is on the ridge 2 miles southeast of Rosebud Lake. All three stocks have similar characteristics, and many of the features of the Salmo River monzonite described in the following paragraph are found in the other two stocks.

The Salmo River monzonite forms large rounded outcrops and open bluffs separated by deep little draws containing weathered monzonite sand. The stock has an elliptical surface outline with axes 3,500 and 2,700 feet long. The contacts, where exposed on surface and in the underground parts of the Canadian Exploration conveyor system (*see* Plate X), dip steeply, and it appears that the stock close to the surface is cylindrical and plunges steeply eastward. The monzonite is a fairly uniform coarse-grained equigranular rock containing about equal amounts of feldspar and mafic minerals. The most abundant mafic mineral is augite, but biotite is always present, and olivine, somewhat altered to serpentine and magnetite, is a minor constituent. About two-thirds of the feldspar is orthoclase cryptoperthite with a blue schiller, and the remainder is plagioclase ranging from oligoclase to labradorite. Textural and compositional variations throughout the stock are small, except near the margin where there is a mafic zone and a compositional banding parallel to the contacts. Contacts are moderately sharp, but quartzite and phyllite within a few feet of a contact contain coarse biotite and are distinguished from the mafic border facies of the monzonite only by their foliation. The surrounding rocks do not appear to have been deformed by intrusion, and it is thought that the stock was emplaced by a passive process involving stoping and assimilation.

Lamprophyre Dykes and Sills

A wide variety of lamprophyre dykes and sills is found throughout the Salmo Area. They range in thickness from a few inches to several tens of feet and vary greatly in strike length. The largest dykes in the map-area cut the volcanic rocks in the lower canyon of the Pend d'Oreille River. Two northerly striking, steeply dipping dykes exposed before flooding of the Waneta reservoir are between 50 to 80 feet thick, and, judging from lineaments on air photos, they extend several thousand feet to the north. Most lamprophyres, however, are less than 10 feet thick. The characteristically pinch and swell and change direction in both strike and dip, so that it is difficult to generalize about their attitude. Many follow foliation planes or contacts between rock units, and consequently along the Pend d'Oreille River one set of lamprophyres strikes between east and northeast and dips south. In the northern part of the Mine Belt they commonly strike north or somewhat east of north parallel to the strike of the foliation. Other lamprophyres occupy fault zones or fractures parallel to them. The northerly striking transverse faults in the Reeves MacDonald mine contain lamprophyres, and many dykes near the mine and westward to the mouth of the Pend d'Oreille River strike north parallel to the transverse faults (*see* p. 60). In the Sheep Creek camp Mathews (1953, p. 31) reports that lamprophyre dykes follow many of the faults.

A quantitative estimate of the abundance of lamprophyres in various parts of the area is difficult because they weather readily and may not outcrop. They are abundant and well exposed in the canyons of the Pend d'Oreille River. Many are found in the Reeves MacDonald mine, but they appear to be no more abundant close to the mine than farther away. Lamprophyres are common in the Mine and Black Argillite Belts and in mines of the Sheep Creek camp. In the Eastern Belt in general, however, and especially in rocks of the Nelway formation, they are not as abundant as in other parts of the map-area. Lamprophyre dykes cut all the other intrusive rocks of the area but are not common within the large granitic stocks.

The dykes are dark coloured and have well-defined contacts and chilled margins. They are aphanitic, porphyritic, or medium grained in texture and range in composition from dark-grey biotite and olivine-rich rocks to light-grey or greenish-grey chloritic rocks. Though most dykes are uniform, compositional and textural banding parallel to the walls of the dykes is a fairly widespread feature. Both angular and rounded fragments of wallrock are present in many of the dykes. Rounded fragments commonly have a marginal reaction rim.

Study of thin sections shows that the dykes contain biotite, olivine, pyroxene, and feldspar, together with talc, serpentine, chlorite, carbonate, and sericite. The proportion of these minerals varies from one dyke to another, and biotite-olivine lamprophyres are the most common. Usually the minerals are euhedral or subhedral, and the groundmass of porphyritic types is felted or has a trachytic texture. Reddish-brown or, rarely, green biotite crystals are present in almost all the dykes. Olivine, the second most abundant and widely distributed mineral, is invariably almost completely altered to talc or serpentine commonly containing carbonate and magnetite. Augite showing little or no alteration is present in many of the dykes as small phenocrysts. Lamprophyres containing significant amounts of feldspar are less common than the biotite-olivine lamprophyres. The plagioclase, which is generally labradorite, forms subhedral phenocrysts or fine crystals in the groundmass. At places rounded clusters of plagioclase and potash feldspar surrounded by flakes of biotite give the rocks an amygdaloidal appearance on weathered surfaces.

Some features of the magmatic history of the dykes are discussed by Mathews (1953, p. 33) on the basis of studies in the Sheep Creek camp. From chemical data he suggests that, despite the wide range in texture and mineralogical composition, the dykes are derived from one magmatic source, and also that the Salmo River monzonite (*see* p. 44) came from the same source. The writers concur with Mathews' suggestions and have noted that the central parts of the largest dykes are commonly similar in texture and mineralogy to the Salmo River monzonite. Lamprophyre dykes cut the monzonite, and their margins are chilled against it.

CHAPTER III.—STRUCTURAL GEOLOGY

Some general features and some details of the structure of the Salmo Area have been known for a number of years. The Ripple Creek fault, a prominent fault in the southeastern part of the area, is described by Daly (1912, p. 279) from work done between 1906 and 1909. The most pronounced curvature of the southern part of the Kootenay arc (*see* p. 9) occurs within the Salmo Area and is clearly shown on the Salmo sheet published in 1934 (*see* Walker, 1934, Map 299A). The Sheep Creek anticline was first described by Walker, and the details of its northern part became known through work in the mines of the Sheep Creek camp (*see* Mathews, 1953). More recently many local faults and folds have been mapped by mine and exploration geologists in the lead-zinc mines and in areas explored for lead and zinc. In the area west of the Sheep Creek anticline, however, neither the large-scale regional mapping nor the detailed work in restricted areas satisfactorily solved the structure. Walker's concept of a broad syncline west of the Sheep Creek anticline (*see* Walker, 1934, p. 19), a concept adopted by Little (1950, p. 34), was based on stratigraphic correlations now known to be incorrect. The existence of eastward- and southward-dipping thrust faults was not suspected until 1950, when Shenon and Full (1951) discovered a southward-dipping regional thrust fault south of the Pend d'Oreille River. In the present work it has been found that three thrust faults of regional extent divide the area into structural belts, the most important of which are the Mine Belt, Black Argillite Belt, and Eastern Belt (*see* Fig. 2). The Mine and Eastern Belts, underlain by Cambrian quartzites, limestones, and argillites, characteristically contain relatively continuous structures. The Black Argillite Belt, underlain by the Active argillite, characteristically contains discontinuous structures. Close studies of appropriate parts of the Mine Belt have determined many structural details and established a pattern of folding and faulting. Few detailed studies have been made in the Black Argillite Belt, but it has been shown that the pattern of folding is consistent with that to the east and west. In the Eastern Belt the Sheep Creek anticline is known in its northern part from previous work in the Sheep Creek camp, and in the present work has been carefully studied in its southern part on Lost Mountain and the South Salmo River. Complex folds on the western limb of the anticline are known in only a general way.

SUMMARY

The structural history of the map-area is a long one, and only the more obvious results of the complex deformation have been recognized. The oldest known structures are overturned and isoclinal folds. They are referred to as primary folds. The primary folds have been folded into structures called secondary. The secondary folds may be open or isoclinal, and are considered to have formed late in the same general period of deformation as the primary folds. Bedding and thrust faults are common and probably originated late in the period of primary folding. Movement continued on these faults during the secondary folding, and hence the faults may be regarded as either primary or secondary structures. All the aforementioned structures are cut by granitic stocks, some of which have marginal zones of complex folding. Folds in these zones, which are later than both the primary and secondary structures, are referred to as late cross-folds. Transverse faults are of several ages, some younger and some older than the granite.

Regionally, the map-area includes the point of maximum curvature of the Kootenay arc. In the northern part of the map-area and for relatively great distances north of it the major structures trend northward. In the southern part of the area structures swing in strike from north through northeast to slightly north of east along the Pend d'Oreille River, and a northeasterly strike continues for several miles to the southwest, in Washington.

The map-area is divided into four major structural belts (*see* p. 16) by three subparallel thrust faults that curve with the Kootenay arc. In the northern part of the area the faults strike northward and dip steeply eastward. Toward the south they change in strike to eastward and in dip to gently southward. The most westerly or Waneta fault separates the Mesozoic volcanic area on the west from the Mine Belt. The second, called the Argillite fault, forms the eastern boundary of the Mine Belt and separates it from the Black Argillite Belt. The third or Black Bluff fault lies on the east side of the Black Argillite Belt (*see* Fig. 2).

Within the belts thus defined, axes of the primary folds follow the regional trend of the Kootenay arc. East of the Salmo River the axes strike northward, farther south they strike northeastward, and along the Pend d'Oreille River they strike eastward. The fold axes plunge mostly at small angles to the south and southwest, but locally they plunge to the north. The axial planes in general dip eastward and southward.

The Eastern Belt is dominated by the Sheep Creek anticline, which extends from the ridge between Sheep Creek and Hidden Creek to the International Boundary. Throughout its length the anticline plunges gently, in general southward, but locally northward, and the axial plane dips steeply to the east. North of the Lost Creek stock the anticline is isoclinal and has a subsidiary syncline and anticline on its western flank. South of the Lost Creek stock the anticline is simple and is more open, although a series of small isoclinal folds lies to the west of the main anticline and extends as far west as the Black Bluff fault.

In the Black Argillite Belt the structural pattern is one of isoclinal folding and related shearing. In general, the foliation dips east and southeast. No major folds and faults have been recognized. Small folds have complex shapes, and are variable in plunge and in attitude of axial planes over relatively small areas.

In the Mine Belt the major primary structures are isoclinal folds and bedding faults. The faults and axial planes of the folds dip eastward or southward. In the northern part of the belt, bedding faults and the axial planes of primary folds dip eastward and are gently folded about axes that are nearly parallel to the primary fold axes. In the southern part of the belt, primary isoclinal folds plunge gently to the west and secondary folds plunge steeply to the southwest.

The major primary structure of the northern part of the Mine Belt is a complex isoclinal anticline, known as the Jersey anticline, which has been traced from near the mouth of the South Salmo River to the south slope of Sheep Creek, and probably continues north to the Hidden Creek stock. North of the Hidden Creek stock on Porcupine Creek the major primary structure is also a complex anticline, the Jack Pot anticline, but the two cannot be correlated. The most prominent structure in the southern part of the belt is the Salmo River anticline, which is flanked by complex folds. The Salmo River anticline is isoclinal, with axial plane dipping steeply southward and axis probably plunging at a low angle westward. To the west, between Church and Harcourt Creeks, it is cut off by thrust faults; to the east it passes into the granitized area between Wallack Creek and the Salmo River.

The primary folds and faults are transected by a number of granitic stocks. The Salmo River anticline and related structures north of it pass to the east into a granitized area between Wallack Creek and the Salmo River with only minor changes in the regional attitude. The Jersey and Emerald stocks cut into the Jersey anticline, and the Lost Creek stock cuts sharply across the Sheep Creek anticline and the Black Bluff fault, but the pre-granite structures continue beyond these stocks with little or no offset. Near the southern margin of the Hidden Creek stock the primary and secondary structures swing abruptly in strike from north through northwest to almost west before ending against the stock. Along the northern margin of the stock the structures are exceedingly irregular, but farther north they resume a northerly trend.

Both primary and secondary structures are offset by transverse faults, some of which are older and some younger than the granitic rocks. Along the International Boundary the main transverse faults strike northward and northeastward and are downthrown on the east. Faults of this set offset the orebodies at the Reeves MacDonald mine. The pattern of transverse faults in the rest of the area is more complex. One set strikes northwestward, and to this set belongs the prominent Ripple Creek fault. Another set strikes northward. A northward-trending fault east of the Jersey mine is older than the granitic rocks, but northward-trending faults near the mouth of Sheep Creek are younger than the granitic rocks.

DETERMINATION OF STRUCTURE

Exploration for lead, zinc, and tungsten in the Salmo Area since about 1940 has led to much speculation in the district regarding the stratigraphy and structure of the rocks containing the known orebodies. The regional maps of Walker and Little, and local observations by exploration geologists, showed that the rock units throughout the Mine Belt probably belonged to the same formations, but a unified stratigraphic section for the belt could not be determined. An apparently simple stratigraphic succession exposed along the Pend d'Oreille River near the Reeves MacDonald mine, for example (*see* White, 1949), could not be matched at the mines to the north, though many of the individual rock types were easily recognizable. Similarly, an apparent thickness of 3,000 feet of limestone with minor non-calcareous interbeds forming the Lower Laib on the north side of Sheep Creek near the H.B. mine (*see* Little, 1950, p. 16) diminished to one-tenth of this thickness less than a mile to the north. Although it was obvious that the rocks were highly deformed, the simplest explanation of these apparent changes in the stratigraphy was that they were sedimentary facies changes. Apparent support of this interpretation is furnished by limestone which, south of the Jersey mine and at a number of other places, tails out along strike into non-calcareous rock within a few hundred feet. Previous workers had presumed sedimentary facies changes in order to correlate rocks in the Eastern Belt with those in the Mine Belt (*see* Little, 1950, pp. 15–17).

At the start of their investigation the writers studied in detail the structural features of the Mine Belt. This study provided a structural interpretation that explained some but not all of the apparent stratigraphic variations. In an attempt to check the validity of the stratigraphic section evolved in this work, studies were made in the relatively simple southern part of the Sheep Creek anticline, and it was found that most individual members could be traced for great distances without much change, and that many members found on the Sheep Creek anticline could be recognized readily in the Mine Belt. Subsequently, the Mine Belt was restudied on the assumption that sedimentary facies changes were minor and that apparent variations in the stratigraphic succession resulted from structural complexities. As the work proceeded it was repeatedly proved that structure and not stratigraphy had caused variations that were previously thought to be sedimentary. Patterns of major folding and faulting and many complex structural details have been worked out in the Mine Belt on this basis.

Very few major structures in the Salmo Area are of such size or are well enough exposed that they may be seen from one observation point or outlined in a study of air photographs. Parts of the Sheep Creek anticline can be seen from the ground (*see* Mathews, 1953, Plate I) and from air photographs, complex structure is well displayed in the cliffs on the northwest side of Truman Hill (*see* Plate IV), and some late faults show up as topographic lineaments, but, in general, interpretation of the structure must be built up from many individual observations. Dragfolds, bedding-cleavage relationships, and cross-bedding have all been used, but knowledge of the stratigraphic section has proved the greatest aid in unravelling the structure. Structural mapping, particularly in the Mine Belt, requires so much interpretation that it seems worth while to draw attention to some of the features by which structure may be determined, and to discuss their significance and the difficulties encountered in their study.

DRAGFOLDS

The study of dragfolds within the map-area is difficult because the dragfolds are of several types, depending on their origin. The principal types recognized are: (1) Those related to primary folds, (2) those related to secondary structures, and (3) those related to late cross-folds. In the Eastern Belt, dragfolds are mainly of the first type. In the Mine Belt, all three types have been recognized. In the Black Argillite Belt, probably the same three types also occur, but structure in the belt is very complex and mapping has not been on a scale that permits recognition of patterns of dragfolds and details of structure.

For descriptive convenience in this report, dragfolds are referred to as being S-shaped and Z-shaped. The term " S-shaped " describes a dragfold with the shape of a letter " S " and the term " Z-shaped " refers to one with the shape of a letter " Z " or reversed " S." These terms apply to all dragfolds, whether the curvature be gentle or abrupt, or whether the dragfold be a mere flexure or one with marked overlap. In general, and unless otherwise specified, the terms refer to cross-sectional shapes as seen in plan or looking down the plunge.

Dragfolds related to primary folds are well displayed in the Eastern belt. They are associated with the Sheep Creek anticline and subsidiary folds on its flanks. Dragfolds plunge parallel to the axes of the major folds, and cross-sectional shapes of dragfolds can be used to indicate the position of a dragfold on a larger fold. Some spectacular dragfolds occur on the eastern limb of the southern part of the Sheep Creek anticline. They are displayed on the Ripple Creek fault scarp (*see* p. 62) south of Lost Mountain in the Nugget member of the Quartzite Range formation. The dragfolds plunge about 10 degrees to the south and measure 30 to 40 feet in amplitude; the anticlinal parts have gently dipping eastern limbs and almost vertical western limbs.

Dragfolds related to primary folds are found also in the northern part of the Mine Belt. Attenuated and isoclinal dragfolds are exposed on Iron Mountain and at a few other places to the north, and are particularly well displayed in road cuts north of the Jersey townsite and in the Jersey mine. More open dragfolds related to primary folds can be seen on the northwest slope of Truman Hill. Dragfolds near the Jersey townsite are on the limbs of primary folds and those on Truman Hill are near the crest of a primary anticline. In general, interpretation of dragfolds in the northern part of the Mine Belt is difficult because of secondary folds, the axes of which are parallel to the primary folds. Primary dragfolds have not been recognized with certainty in the southern part of the Mine Belt; possibly they have been obliterated by shearing.

The most prominent dragfolds in the Mine Belt are related to secondary structures. In the northern part of the Mine Belt relatively open secondary folds plunge gently north or south and have secondary dragfolds associated with them. West of the Jersey and H.B. mines the dragfolds are outlined in phyllitic rocks by folded cleavage and in limestone by gently folded banding. In the southern part of the Mine Belt secondary dragfolds plunge steeply southwest and are almost entirely Z-shaped in plan. The folds range from gentle flexures to attenuated dragfolds with overlap many times the thickness of the beds involved. Several large steeply plunging folds have been recognized and have dragfolds related to them. All the steeply plunging dragfolds are superimposed on the gently plunging Salmo River anticline and on the primary folds north and south of it. The dragfolds show that there has been a regional differential movement of the south side of the Mine Belt westward. Some of this movement has been taken up by the dragfolds and some by shearing on bedding faults.

Steeply plunging dragfolds associated with late cross-folds are found near the Hidden Creek stock in all three belts. On the north slope of the ridge north of the Reno mine dragfolds of this type plunge steeply northeast, near the Aspen property they plunge north and northeast, and near the Jack Pot property they plunge steeply south. Steeply plunging dragfolds of the same general type occur in the northern part of the Black

Argillite Belt. Too little mapping has been done in the Black Argillite Belt to determine the significance of these folds. Near the H.B. mine, on both sides of Sheep Creek and for a considerable distance north of the creek, dragfolds plunging steeply eastward and northeastward are common. They are related to a local abrupt swing in strike of the strata that may be referred to as a late cross-fold. The dragfolds associated with it are complex and relatively open. The relationship between this cross-fold and those near the Hidden Creek stock is uncertain.

SECONDARY FOLIATION

Most of the rocks of the map-area have a more or less well-developed secondary foliation* resulting from a parallel orientation of micaceous minerals. This foliation varies with mineral composition. Micaceous rocks have the strongest foliation; quartzites and limestones containing little mica are as a rule poorly foliated. Secondary foliation also varies with structural situation. In the map-area it varies from one belt to another and at places in each belt is partly obliterated by thermal metamorphism.

In the Eastern Belt rocks in the Sheep Creek anticline below the Reeves limestone have a poor cleavage. In the southern part of the Sheep Creek anticline cleavage is parallel to the bedding and can be traced around the crest of the anticline. In a few places a poor cleavage is approximately parallel to the axial plane of the anticline. In the Sheep Creek camp Mathews (1953, p. 38) reports: "A crude schistosity parallel to the stratification and, less commonly, a fracture cleavage roughly parallel to the axial planes of adjoining folds" in the more micaceous quartzites. In the southern part of the anticline in rocks of the Upper Laib a strong cleavage strikes northeastward and dips steeply southeast parallel to the axial plane. At many places on both limbs and on the crest of the anticline cleavage crosses the bedding, and small folds have axial planes parallel to this cleavage. North of the Lost Creek stock, bedding transects cleavage in rocks of the Upper Laib, but both bedding and cleavage are obscured by thermal metamorphism. In the southern part of the Eastern Belt the strike of the foliation swings from north 35 degrees east between the Lost Creek stock and South Salmo River to north 50 to 60 degrees east, south of South Salmo River. This swing is parallel to the swing in the strike of axial planes of minor folds on the western side of the Sheep Creek anticline.

Cleavage has been partly obscured by metamorphism in rocks above the Reno quartzite on the western side of the Sheep Creek anticline, between the Lost Creek and Hidden Creek stocks. Metamorphic minerals such as knots of quartz and biotite in argillaceous rocks, or garnet and diopside in calcareous rocks, developed with random orientation following the main period of deformation. Blocky hornfels or skarn and poorly foliated biotite schists have resulted, cleavage has been obscured, and locally banding parallel to the cleavage has formed.

In the northern part of the Black Argillite Belt cleavage has been partly obscured by metamorphism. The argillites tend to be more blocky north of the South Salmo River than south of it, and near the Hidden Creek stock they are very blocky. Silicated rocks near the head of Wilson Creek and silicified argillites between the Reno mine and the head of Aspen Creek are banded and very poorly cleaved. Study of foliation is hampered in the northern part of the Black Argillite Belt by rusty-weathered rock surfaces.

In the southern part of the Mine Belt the rocks have a strong secondary foliation. Most of the quartzites at the core of the Salmo River anticline have a pronounced cleavage, and the more micaceous rocks are schistose. Locally, limestones containing a small proportion of muscovite have a good cleavage, and the purest white quartzites are sheeted or break on closely spaced joint planes parallel to the cleavage in the surrounding rocks. In general, the secondary foliation is parallel to the beds. The rocks are isoclinally folded, and at a few places where the crest of a fold can be seen or inferred, the cleavage is approximately parallel to the axial plane of the fold and does not follow the beds around the crest (*see* Plate XI). The foliation is locally gently warped about axes that plunge steeply southwestward, but in general it strikes uniformly east and dips 50 to 60 degrees south. On the Pend d'Oreille River, cleavage is strongest immediately north of the Argillite fault and becomes less well developed toward the Reeves MacDonald mine.

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* In this bulletin "secondary foliation" is used as a general term for all secondary planar structures of which cleavage and schistosity are most common. Cleavage is a descriptive term referring to the ability of a rock to break into slabs or plates. Schistosity is used to describe the secondary foliation of schists. No distinction is made between flow cleavage and fracture cleavage. Foliation without a qualifying adjective refers to bedding, cleavage, or schistosity where these cannot be readily distinguished from one another.

Rocks in the northern part of the Mine Belt are as intensely deformed as those in the south, but granitic intrusions and the attendant thermal metamorphism have tended to obscure the secondary foliation. Cleavage is poorly developed in the northern part of the Mine Belt and is usually parallel to the bedding. Commonly the cleavage can be followed around the crests of small folds and locally of large ones. At a few places cleavage in micaceous quartzite cuts across the bedding and is approximately parallel to the axial planes of the folds.

Locally, in micaceous quartzites in which cleavage can be distinguished from bedding, cleavage has been accentuated by bleaching and grades into a regular banding. It is inferred that at many places banding in micaceous quartzites, and probably in other rocks also, is the result of alteration along cleavage planes.

FACTORS AFFECTING THE RECOGNITION OF ROCK TYPES

The structure of the Mine Belt has been determined mainly from knowledge of the stratigraphic sequence and recognition of markers in the Quartzite Range, Reno, and Laib formations. The sequence below the Reeves limestone is now well known and has been found to contain several good markers; it is, therefore, most useful in structural determinations. From place to place, recognition of rock types is hampered either by original sedimentary facies changes or by variations in metamorphic grade. Sedimentary facies changes are minor, but locally thermal metamorphism has changed the rocks to such an extent that only the most distinctive markers can be recognized. Many variations in the lithological characteristics of the rock units were noted in Chapter II, and the most important are summarized in the following paragraphs. Emphasis in the following is placed on field recognition, lithologic correlation, and the determination of structure, and not on processes of sedimentation and metamorphism.

Sedimentary Facies Changes

The Quartzite Range, Reno, and the lower part of the Laib formation can be traced for several miles on the southern part of the Sheep Creek anticline. Close mapping has shown that the rock types are remarkably uniform in sedimentary characteristics and that the units are very similar to their correlatives in the Sheep Creek camp north of the Lost Creek stock. In the Mine Belt the same units and the same stratigraphic sequences are found, and the rock types are only slightly different in sedimentary characteristics from those on the Sheep Creek anticline. Throughout the Mine Belt itself detailed studies have revealed no pronounced sedimentary facies changes. Differences noted between quartzitic rocks on the Sheep Creek anticline and those in the Mine Belt indicate that somewhat coarser-grained rocks lie to the east. Determination of the structure of the Mine Belt has been possible only because of the uniform stratigraphy.

In quartzitic rocks sedimentary facies changes include minor changes in grain size and in cross-bedding. On the Sheep Creek anticline the Upper Reno contains fairly continuous beds in which quartz grains one-eighth to one-quarter of an inch are common and in which cross-bedding is prominent. In the Mine Belt the Upper Reno contains distinguishable quartz grains only in lenses; the grains are rarely more than one-eighth of an inch in diameter and the quartzite is not cross-bedded. Similar differences between the Mine Belt and the Eastern Belt have been noted in the size of detrital quartz grains and in cross-bedding of the Upper Nugget and Upper Navada quartzites. Within each belt the sedimentary characteristics are relatively uniform.

The Emerald member of the Laib formation is a distinctive black argillite immediately overlying the Reeves limestone in the Mine Belt. The Emerald black argillite has not been found on the Sheep Creek anticline, but, instead, the Reeves limestone is overlain by a purplish-grey siliceous argillite. This change is regarded as a sedimentary one, but whether the Emerald argillite grades eastward into the purplish-grey siliceous argillite or grades into the upper part of the Reeves limestone, or whether the Emerald member was deposited only in the west, is not known.

The Lower Navada member of the Quartzite Range formation contains green phyllite and thin lenses of grey limestone on the Salmo River anticline. Similar rocks occur on the south side of Porcupine Creek in rocks tentatively correlated with the Lower Navada, but no limestone and very little green phyllite has been found in the Lower Navada elsewhere. It is concluded that the limestone and part of the green phyllite represents a western facies which was not laid down in the east.

Metamorphism and Alteration

Metamorphism and rock alteration have changed the appearance of rock units and have thereby complicated lithologic correlations. Two general types of metamorphism, one referred to as regional and the other as thermal, have affected the rocks in the map-area. Low-grade regional metamorphism resulting mainly from close folding and strong shearing has affected all the rocks in the map-area. Thermal metamorphism associated with granitic intrusion is more local, but has produced more prominent changes. Structures to which regional metamorphism is related are cut by granitic rocks, and thermal metamorphism has been superimposed on rocks that have been regionally metamorphosed. In general, rocks in the southern part of the map-area do not appear to have been thermally metamorphosed except in narrow zones bordering the Lost Creek stock and the monzonite stock south of the South Salmo River, and in a narrow granitized zone south of the Wallack Creek stock. All rocks in the northern part of the Mine Belt and along the western side of the Eastern Belt north of the Lost Creek stock have been thermally metamorphosed and locally have been granitized.

Rocks in the southern part of the map-area that do not appear to have been affected by thermal metamorphism are quartzites, phyllites, and fine-grained schists containing quartz, calcite, muscovite, and minor chlorite. Thermally metamorphosed rocks in both the southern and northern parts of the map-area contain quartz, biotite, lime-silicates, and locally feldspars; they include hornfels, skarn, and gneiss. The following descriptions emphasize field characteristics that affect the stratigraphic correlations of metamorphic rocks.

In the Quartzite Range, Reno, and Laib formations, quartzitic rocks have been only slightly changed by thermal metamorphism. White quartzites have been recrystallized. They contain recognizable sedimentary quartz grains through most of the Sheep Creek anticline and in places on the Salmo River anticline, but only recrystallized quartz in the Mine Belt near Lost Creek and along Porcupine Creek. Although white quartzites have been granitized near the Wallack Creek stock and in the upper part of Hidden Creek, they can be traced for greater distances into the granitized zones than can the other rocks adjacent to them.

Micaceous quartzites of the Lower Navada and Lower Reno on the southern part of the Sheep Creek anticline have a poor cleavage and contain rounded quartz grains, fine flakes of muscovite, and minor amounts of chlorite and green to brown biotite. On the Salmo River anticline, rocks of the same units are of similar composition but have a strong cleavage, and thin sections show that the quartz and the micaceous minerals have a marked crystallographic orientation. In contrast, micaceous quartzites on Truman Hill and north of it have a poor cleavage and contain, as seen under the microscope, quartz, red-brown biotite, and more or less muscovite. The micas are in bands, but with only a poor orientation, and locally biotite flakes are arranged in clusters which give weathered surfaces a spotted or blotchy appearance.

Characteristically, some beds in the Upper Reno quartzite are made up of rounded quartz grains cemented by calcite, and these beds are pitted on weathered surfaces. In the northern part of the Mine Belt, particularly on Iron Mountain, diopside, garnet, and epidote occur with or without calcite between the quartz grains. Fresh surfaces are dark green, and weathered surfaces lack the pitting. On the Salmo River anticline the quartzite is sheared, the quartz grains are distorted, and pitted weathered surfaces are uncommon.

Rocks of the Truman member on the southern part of the Sheep Creek anticline are poorly cleaved green and grey phyllites containing quartz, muscovite, and minor chlorite. The same minerals are found in the Truman member on the Salmo River anticline, but the rocks are strongly sheared and locally contain porphyroblasts of brown biotite and chloritoid. In the northern part of the Mine Belt and in the Eastern Belt west of the Sheep Creek camp, rocks of the Truman member are biotite hornfels and garnet-pyroxene granulites referred to locally as argillite, skarny argillite, and skarn. They are green and brown, fine-grained, poorly cleaved rocks which, on fresh surfaces, have a prominent colour banding. Microscopically, brown argillites contain quartz, red-brown biotite, and muscovite. The micas occur in bands in which individual flakes are poorly oriented. Biotite locally forms clusters, with the result that the weathered surfaces are spotted. Green bands in skarny argillites contain calcite, diopside, and minor amounts of zoisite. More calcareous parts of the Truman member contain medium- to coarse-grained garnet and diopside. On Iron Mountain garnet-diopside skarn is a brown to green, poorly banded rock occurring mainly in the Truman member and base of the Reeves limestone.

The appearance of the Reeves limestone is affected by dolomitization, silication, and textural variations. Characteristic features of the limestone are described in Chapter II (p. 25) and dolomitization is discussed in Chapter IV (p. 84). Fine-grained, poorly banded grey limestone on the southern part of the Sheep Creek anticline contrasts with well-banded limestone in the Mine Belt. Characteristic, finely crystalline limestone in the Mine Belt becomes finer grained where dolomitized and coarser grained where thermally metamorphosed. The banding may be partly or completely obscured by dolomitization, thermal metamorphism, or shearing. Dolomite in the Reeves limestone west of the H.B. mine is light grey to white and massive. Dolomitized zones near the main orebodies have a flecked or wispy banded texture probably resulting in part from deformation and in part from dolomitization. Near the Aspen and Jack Pot mines, close to the Hidden Creek stock, the Reeves limestone in places is a white, coarsely crystalline marble.

Along the Pend d'Oreille River near the Reeves MacDonald mine several bands of Reeves limestone repeated by folding show a remarkable contrast in appearance. Two bands on the limbs of the Salmo River anticline—one at the mine and the other along the lower Salmo River—are grey and white to well-banded finely crystalline limestone, characteristic of the Reeves member in the Mine Belt. A band immediately south of the Reeves MacDonald mine, known locally as the Prospect member, is mainly light-grey, very poorly banded fine-grained dolomite. On both sides of the Pend d'Oreille River it contains a large lens of black siliceous dolomite (*see* Fig. 17). Farther south, near the Argillite fault, limestone with interbanded schist is grey, lacks banding, and has a strong cleavage. Correlation of these four bands of limestone with the Reeves member is not obvious because of their contrasting appearance. The correlation was possible only in the light of knowledge of the rock sequence above and below the limestone and of the structural pattern near the Reeves MacDonald mine.

REGIONAL THRUST FAULTS

The main structural belts in the map-area are separated by three regional thrust faults. The faults are old structures which probably originated during the primary folding and on which movement continued through the period of secondary folding (*see* p. 47). The faults are older than the granitic stocks, and in much of the map-area rocks in the fault zones and adjacent to them have been thermally metamorphosed. Zones of breccia, mylonite, and intense shearing are found only locally along the faults, and at many places where they are exposed the faults are not impressive zones of shearing. Detailed tracing of rock types and mapping of structures close to the faults reveals that they transgress at acute angles both rock members and primary fold structures.

The three faults recognized are the Waneta, Argillite, and Black Bluff faults. The Waneta fault, named from exposures of the fault along the south side of the Waneta reservoir, separates the Mesozoic volcanic area from the Mine Belt; the Argillite fault forms the eastern boundary of the Mine Belt; and the Black Bluff fault, named from the Black Bluff on the Nelson–Nelway highway, separates the Black Argillite Belt from the Eastern Belt.

In the northern part of the map-area the faults strike northward and dip steeply east. Farther south they swing in strike to southwest and dip less steeply southeast. Along the Pend d'Oreille River the faults strike west and dip gently south. No estimate of movement on the faults has been possible. They are regarded as thrust faults mainly because of their relationship to primary folds. On the Waneta fault Lower Palæozoic rocks have overridden Mesozoic rocks, and on the Black Bluff fault Cambrian rocks have overridden Ordovician. On the Argillite fault Ordovician rocks have overridden Cambrian rocks. Early movements on the faults probably differed from late movements and, because of the regional swing in strike, movement in the northern part of the map-area differed from that in the south. Patterns of folds in the Mine Belt suggest that in the northern part of the area the faults continued as thrusts during the formation of secondary folds. In the southern part they originated as thrusts and, during the secondary folding, acted as tear faults with strike slip dominant.

In addition to the major thrust faults, many smaller faults are found within the belts. Many of these faults are probably thrusts, but they are referred to as bedding faults because, in general, there is little direct evidence that they are thrusts, and in individual exposures all that is known is that they are parallel to the surrounding foliation. The major thrust faults and the smaller bedding faults have the same appearance. They are probably closely related in origin and apparently have produced the same type of displacement.

WANETA FAULT

The Waneta fault has been traced from south of the International Boundary near Waneta along the south side of the Pend d'Oreille River for about 2 miles. From the south side of the river it is displaced northward by a transverse fault and continues eastward along the north side of the river into an area of heavy cover and granitic rocks between Tillicum and Limpid Creeks. It is transected by the granitic mass between the head of Limpid Creek and the Salmo River. North of this granitic mass the fault has been found west of the Salmo River just south of the mouth of Sheep Creek and has been recognized again on the east side of the river and traced north to the Hidden Creek stock west of Woodchuck Creek. The Waneta fault has not been recognized north of the Hidden Creek stock.

About 6,000 feet east of the Waneta dam the Waneta fault is marked by a zone of mylonite 30 to 40 feet thick. The mylonite is a black, very fine-grained rock containing rounded and eye-shaped fragments ranging from a fraction of an inch to a few feet across. The fragments include fine-grained massive grey rock of uncertain origin, black argillite, and grey limestone. The mylonite has a vague wavy banding that strikes east and dips 30 to 35 degrees south, and locally shows minor folds plunging about 30 degrees southward. The banding indicates that the fault dips to the south, and this is confirmed by its surface trace in crossing Cedar Creek, 3,500 feet east of the Waneta dam. North of the river the trace of the fault swings in accordance with the topography, and estimates made from mapping the trace as it crosses Nine Mile Creek indicate that the fault dips about 20 degrees to the south. Commonly, greenstones within about 100 feet of the fault are schistose, but farther from the fault they are blocky and massive. Locally, zones of mylonite like that exposed on the south side of the river occur along the fault. East of Charbonneau Creek the fault is followed by a felsite sill about 100 feet thick. Rock units in the volcanic sequence have not been traced, but mapping of the limestone-argillite contacts south of the fault shows that the fault cuts across formational boundaries at acute angles. In general, the regional strike of the formations appears parallel to the fault and the regional dip is steeper.

Near the Riverside Placer camp, rocks of the Mine Belt close to the fault are black slates with very prominent cleavage, and rocks of the volcanic sequence north of the fault are schistose greenstones containing rusty-weathering lenses of carbonate and disseminated pyrite. Schistosity in the greenstones is confined to a zone which is about 100 feet thick, but which outcrops locally for a considerable distance from the river because of its southerly dip. Away from this zone of schistosity the greenstones are massive and blocky. Along the river where the contact is exposed, black slates grade, in a few feet, into green schist and phyllite. The schistosity strikes eastward and dips 20 to 30 degrees southward.

Schistosity in the greenstones and cleavage in the slates is deformed into open folds which range in amplitude from a few feet to a few tens of feet and plunge gently southward. These folds in the schistosity and cleavage lie within the general fault zone and are part of larger open folds of the fault zone itself. The presence of these folds and the fact that the fault is almost parallel to the north slope of the river account for the wide swing in the trace of the fault near the Riverside Placer camp.

West of the Salmo River, in the vicinity of Sheep Creek, the Waneta fault is marked by a zone a few hundred feet wide in which schistosity strikes northward and is vertical or dips steeply eastward. On Porcupine Creek the Waneta fault has not been found, but it may pass through an area of metamorphic rocks west of the Double Standard glory-hole (*see* Fig. 3). Thermal metamorphism and granitization have obscured stratigraphic and structural evidence of the fault in this area.

ARGILLITE FAULT

The Argillite fault is so named from the fact that it forms the northern and western boundary of the Black Argillite Belt. The fault was first recognized in the summer of 1950 by Shenon and Full (1951) in the area south of the Pend d'Oreille River and east of Harcourt Creek. It is identified as a major fault extending from Church Creek near the International Boundary to the ridge north of Oscar Creek east of Ymir.

The most westerly exposure of the Argillite fault is between the south and west forks of Church Creek, west of which there is insufficient outcrop to locate even its approximate position. The fault is displaced northward from Church Creek to the head of Fraser Creek and from there east is well exposed as far as the head of Red Bird Creek. It is difficult to locate between Red Bird Creek and the Pend d'Oreille River but is ideally exposed on both banks of the river. The fault can be traced intermittently east of the river. Near Shenango Canyon it cannot be recognized with certainty because other faults are close to it. The Argillite fault is offset by a fault assumed to follow the Salmo Valley, called the Salmo Valley fault. The offset is about 3 miles, and the next appearance of the Argillite fault northeast of Shenango Canyon is near the mouth of the South Salmo River.

The Argillite fault is exposed where it crosses the South Salmo River near the mouth of Lost Creek but is difficult to locate on the wooded slope to the west. To the east it is covered in the valley of the South Salmo River and is offset by the Iron Mountain fault (*see* p. 62) east of Truman Hill. The Argillite fault is found on the south side of Lost Creek, on the east side of the Iron Mountain fault, and probably extends north across Lost Creek beneath the gravel cover. Between the north side of Lost Creek and the south side of Annie Rooney Creek the Argillite fault is concealed by the Iron Mountain fault. The Argillite fault crosses the ridge north of Annie Rooney Creek and is exposed on surface and underground at the H.B. mine.

It has been traced northward to the south side of the Hidden Creek stock near the Aspen mine and has been located north of the Hidden Creek stock on the Jack Pot property. North of Porcupine Creek the fault is difficult to recognize because it is obscured by many transverse faults.

South of the Pend d'Oreille River the Argillite fault dips gently southward. This is shown by the marked swing in the trace of the fault in accordance with topography and by a drill-hole near the head of Church Creek. The hole (*see* p. 155) drilled by The Consolidated Mining and Smelting Company of Canada, Limited, indicates an average southerly dip of 15 degrees for the Argillite fault in this area.

Where exposed on both sides of the Pend d'Oreille River south of the Reeves MacDonald mine, the Argillite fault strikes north 65 degrees east and dips 55 degrees southeastward. On the south side of the fault, black limy argillite of the Active formation is very highly contorted into small, complex, and irregular tight folds. The fault zone contains 6 to 10 feet of irregularly crenulated black schist, north of which lies a strongly cleaved blue-grey limestone, possibly part of the Reeves limestone. Exposures on both banks of the river show the cleavage and formational contacts to lie parallel to the fault zone. Study only of exposures along the river gives no clear evidence that the Active argillite and Reeves limestone are here separated by a regional fault, but detailed study at greater distances from the river shows the contact to be transgressive. An abrupt flattening in dip of the Argillite fault appears to cause a jog in the fault trace on the hill south of the Reeves glory-hole. The jog does not appear to be caused by a transverse fault similar to the O'Donnell and B.L. faults near by.

South of the South Salmo River the Argillite fault dips gently southward, and on the south side of Lost Creek it dips gently to the southeast. Between the ridge north of Annie Rooney Creek and the head of Aspen Creek, the Argillite fault strikes northward and dips steeply to the east.

On the 3500 level of the H.B. mine a zone of interbanded limestone, black crenulated phyllite, and black argillite about 250 feet wide separates the Active argillite from the Reeves limestone. Within this zone the limestone resembles the Reeves limestone, some of the phyllite resembles the Emerald member, and the black argillite may be part of the Active formation. Most of the contacts between limestone and phyllite or argillite are simple, and do not resemble faults, but others are marked by narrow bands of crushed rock which probably are late faults and have caused some of the repetitions of limestone, phyllite, and argillite. Some repetitions may be slivers related to the Argillite fault or isoclinal infolds of the Reeves and Emerald members. On the 3100 level, about 1,200 feet from the portal, the Active argillite is in contact with the lower part of the Reeves limestone, which contains thin partings of brown argillite. The contact is vertical and has the appearance of a simple stratigraphic contact. Banding in the limestone is parallel to that in the black Active argillite, and all the banding follows round a series of small irregular dragfolds. The same contact is repeated by faulting 115 feet to the west along the level, where it dips 70 degrees eastward and is marked by 6 inches of gouge. Although on both the 3100 level and the 3500 level the contact does not appear to indicate a major fault, it is not a normal stratigraphic contact because the rock sequence on the 3500 level is different from that on the 3100 level. The original characteristics of the Argillite fault have been modified by subsequent folding and thermal metamorphism.

North of the Hidden Creek stock, on the Jack Pot property, the Argillite fault in general strikes northward and dips steeply to the east, but near the portals of the 4100 and 4400 levels it strikes northward and dips to the west parallel to the formational trend. The fault brings black argillite of the Active formation into contact on the west with limestone and brown argillite of the Truman member of the Laib formation. Near the portals of the 4100 and 4400 levels several narrow zones of shearing occur in the Active argillite near the Argillite fault, but where the fault is exposed about 2,400 feet from the portal of the 4100 level there is no shearing. The fault is parallel to banding in the rocks on either side of it. Limestone of the Truman member adjacent to the fault is squeezed into eye-shaped masses several inches across. In the Jack Pot area in general the rocks have been warped and metamorphosed since the movement on the Argillite fault, and consequently the original character of the fault has been disguised and modified.

BLACK BLUFF FAULT

The Black Bluff fault separates the Black Argillite Belt from the Eastern Belt, and has been named from exposures of the fault at the Black Bluff on the Nelson–Nelway highway near the mouth of Creggan Creek. It has been projected northeast across a heavily covered area to Rosebud Lake, where it is exposed in the workings of the Lone Silver mine. From the mine it continues northeastward across the South Salmo River on the east side of Wilson Creek to the south side of the Lost Creek stock. North of the Lost Creek stock the fault follows the western contact of the Reeves limestone from the east side of the pass between Nevada Mountain and Mount Waldie to the north slope of Sheep Creek. It has been recognized again west of the Reno mine and on the northern slope of the ridge west of the mine, where it swings westward to the Hidden Creek stock. Studies in this area and in the Hidden Creek valley to the north have not been as detailed as those to the south, but the contact between the rocks of Hidden Creek and the Active argillite to the north, as exposed on the ridge between Active and Hidden Creeks, is regarded as the northern extension of the Black Bluff fault (*see* Fig. 2).

Southwest of Shenango Canyon the Black Bluff fault cannot be recognized with certainty because it is offset by a number of transverse faults. The Salmo Valley fault (*see* p. 63), which offsets the Argillite fault, probably offsets the Black Bluff fault also, and the three faults converge near Shenango Canyon. South of the Pend d'Oreille River the Black Argillite and Eastern Belts are separated by a fault known as the Day fault (*see* Fig. 2). Possibly the Day fault is the southwesterly continuation of the Salmo Valley fault, and the Black Bluff fault is under the Nelway formation southeast of the Day fault.

Throughout its length the Black Bluff fault brings rocks of the Laib or Nelway formations into contact with those of the Active formation. The fault cuts acutely across strata from the Reeves limestone of the Laib formation to the middle dolomite member of the Nelway formation. Although the stratigraphy of the Active formation is not known, the fact that at different places different rock types in the Active formation lie immediately west of the fault indicates that the fault also cuts across stratigraphic units in the Black Argillite Belt. On a regional scale, structures in the Eastern Belt are bevelled acutely by the fault.

At the Black Bluff the fault is exposed for a vertical distance of more than 150 feet above the Nelson–Nelway highway. The fault strikes north 70 degrees east and is almost vertical. It is marked by a zone of sheared and crushed rock a few feet thick containing irregular weathered masses of lamprophyre. The attitude of the beds on either side of the fault is discordant. Immediately south of the fault the beds strike north 60 to 65 degrees east, but farther south they swing to strike more nearly northeast. Northwest of the fault for a few hundred feet both bedding and cleavage strike east and dip 50 to 60 degrees south. Dolomite, limestone, and phyllite of the lower Nelway and Upper Laib formations lie on the southeast side of the fault and black argillite of the Active formation is on the northwest. Masses of dolomite ranging from small lenses to discontinuous beds a few tens of feet thick are highly fractured and at places are cut by a mosaic of thin white calcite and dolomite veinlets. Minor faults with polished graphitic fault planes parallel to or crossing the beds are common in the Active argillite. Farther north the beds are warped into a series of steep southward-plunging dragfolds.

About 130 feet above the highway the fault zone was once exposed in a short adit, but the rock around the adit was blasted away when the highway was widened in 1956. The adit was driven into a lens of brecciated dolomite containing minor amounts of galena and lying between carbonaceous slate on the north and platy argillaceous limestone of the Nelway formation on the south. In the adit the strike of the fault was east and the dip was 45 degrees south; steeply dipping, northerly striking left-hand faults offset the fault a few feet. The fault is also exposed to the southwest below the highway in a bulldozer cut where it separates blocky brecciated dolomite from fissile black argillite. The fault here appears to strike between north 55 and north 80 degrees east and to dip from 30 to 40 degrees southeast. Mullion-like grooves on the dolomite plunge about 35 degrees southeastward.

These details serve to show that the Black Bluff fault plane is irregular, locally nearly vertical, and elsewhere dips more gently to the southeast. The fault plane is well defined, but brecciation and shearing directly related to movement on the fault extends for several tens of feet into both the hangingwall and footwall. Beds and structures cut by the fault tend to swing into near parallelism with it.

At the Lone Silver mine about 2 miles northeast of the Black Bluff, the Black Bluff fault brings dolomite of the middle member of the Nelway formation into contact with Active black argillite. Outcrops along the fault zone near the workings are scarce, and it is not possible to project contacts and fault planes from one working to the next (*see* p. 130), but it is obvious that the workings are in a complex zone of faulting. Dolomite in the workings is highly fractured and crumbles into fragments 1 or 2 inches across. Black carbonaceous argillite of the Active formation is locally sheared to a soft graphite schist. In the few exposures in the workings no pattern of rock distribution or faulting has been recognized. Several faults strike eastward and dip southward, but one eastward-striking fault dips 55 degrees to the north. One fault strikes north and dips 40 degrees east. Another striking northeast and dipping steeply southeast has gently plunging mullions on the fault plane and appears to be a tear fault. Possibly the eastward-striking faults are also tears and the gentle east-dipping fault is a thrust.

The trace of the Black Bluff fault, projected from Shenango Canyon through the Black Bluff and the Lone Silver mine to the top of the slope south of the South Salmo River, is remarkably straight. If the Styx Creek fault is disregarded (*see* p. 62), an average strike of about north 70 degrees east is indicated for the Black Bluff fault. The fault trace curves eastward down the steep south slope of the South Salmo River. This curve could indicate an average southeasterly dip of 35 to 45 degrees, but the trace of the fault swings without regard for topography on the north side of the river.

North of the Lost Creek stock there is little direct evidence of the Black Bluff fault. The principal evidence is the regional relationship between the Active and Laib formations. Members and structures in each formation are truncated at acute angles along a line considered to be the Black Bluff fault. North of the Lost Creek stock the fault is exposed only on the north slope of the ridge west of the Reno mine, and at that locality it could represent a normal bedded contact. Blocky, thinly banded black argillite on the west is in contact with banded grey and white limestone on the east. Where exposed, banding in the limestone and black argillite is parallel to the contact and follows it around a series of dragfolds related to a deformed zone near the Hidden Creek stock. The banding is probably related to shearing rather than to bedding. Metamorphism and late cross-folding (*see* p. 77) have modified original features of the fault zone.

TRANSVERSE FAULTS

The regional thrust faults and primary and secondary structures are offset by late faults. These are referred to as transverse faults to distinguish them from thrust and bedding faults and to indicate that in general they cross the formational strike. The faults range in size from small ones seen only in underground workings to ones that can be traced for miles; a few can be recognized as topographic lineaments. Most transverse faults can be fairly accurately located though the faults themselves are rarely exposed. A fault along the Salmo Valley north of Shenango Canyon is inferred from the regional structure on either side of the valley.

Transverse faults are diverse in attitude. Northerly striking faults occur throughout the area and are abundant in the southern part west of Nelway. Many west of Nelway dip east and are downthrown on the east. In the northern part of the map-area several faults strike northwest and are downthrown on the northeast. Very few northeastward-striking transverse faults have been found in the present map-area, although veins in the Sheep Creek camp occupy northeastward-trending faults (*see* Mathews, 1953, p. 38), and many faults in the Metaline quadrangle strike northeast (*see* Park and Cannon, 1943; Dings, 1956).

All the transverse faults are younger than the primary and secondary folds and the bedding and thrusts faults (*see* p. 47), and many are younger than the granitic rocks. Two northwestward-trending faults in the Jersey mine cut the Emerald stock, and northward-trending faults west of Woodchuck Creek cut the southern part of the Hidden Creek stock (*see* Fig. 2). The Iron Mountain fault, a northward-trending fault east of Iron Mountain, is cut by the Emerald stock (*see* Fig. 3) and is therefore older than the granitic rocks. All the northward-trending faults along the Pend d'Oreille River are probably of the same age, and those at the Reeves MacDonald mine are younger than the orebodies.

In the following paragraphs, descriptions are given of the major transverse faults in the map-area. Relatively small transverse faults near the lead-zinc mines are described in Chapter V.

FAULTS NEAR THE PEND D'OREILLE RIVER

Faults near the Reeves MacDonald mine are typical of a number of faults along the Pend d'Oreille River and are relatively well known. Two faults—the B.L. and the O'Donnell (*see* p. 142)—are exposed underground and offset the Reeves orebody. They are normal faults that strike north and dip about 45 degrees east. Estimates based on the displacement of the Reeves orebody indicate that the B.L. fault has a dip slip of 775 feet and a left-hand strike slip of 275 feet, and that the O'Donnell fault has a dip slip of 1,850 feet and a left-hand strike slip of 125 feet. The fault zones, where exposed, contain a few feet of sheared rock and a small amount of gouge and are followed by more or less sheared and altered lamprophyre dykes. A third, the Point fault, is exposed about 2,000 feet west of the portal of the 1900 level on the north bank of the Pend d'Oreille River as a narrow zone of sheared rock and altered lamprophyre. The fault dips east and is a normal fault, probably with a dip slip of the order of 1,000 feet and a left-hand strike slip of about 500 feet. The Point fault offsets another transverse fault which crosses the Pend d'Oreille River about 500 feet downstream from the place where the Point fault is exposed. This western transverse fault strikes north 35 degrees east and dips about 60 degrees southeast and also appears to be a normal fault downthrown on the east. Similar faults occur on the Red Bird property west of the Reeves MacDonald mine. One has been found on the ridge northwest of the Red Bird adit portal, another is west of the portal in Red Bird Creek, and a third is on the south side of Red Bird Creek about half a mile west of the adit portal.

Between the Red Bird property and the Columbia River, three major transverse faults have been found. One runs between Church Creek and Fraser Creek, another is east of Seven Mile Creek, and a third is along Reith and Lime Creeks. They appear to be of the same general type as those near the Reeves MacDonald mine. The fault between Church Creek and Fraser Creek strikes north 35 degrees east and, judging from its surface trace, dips southeastward. The fault near Reith Creek is marked by a breccia zone which, where exposed on the north bank of the river before flooding of the Waneta reservoir, dips 65 degrees east. All three faults have left-hand offsets which probably indicate a normal dip slip.

South of the Reeves MacDonald mine two northerly trending faults are exposed on the Pend d'Oreille River near the International Boundary. They mark the eastern and western contacts of a narrow wedge of the Active formation that crosses the Nelway formation. The faults are well exposed along the Pend d'Oreille River at low water. The western fault runs north from the south side of the river to the centre of the channel north of the island near the mouth of Slate Creek. The fault plane, exposed near the island at low water, dips 50 degrees east and swings abruptly in strike from north to northwest as it passes around the north side of the island. The fault is marked by a few feet of finely brecciated dolomite on one side against sheared and contorted black argillite on the other. Striations plunge down the dip of the fault plane. The fault on the eastern contact of the wedge of Active formation, referred to south of the International Boundary as the Monument fault (*see* Dings, 1956), is marked by a zone of brecciated dolomite as much as 500 feet wide which occurs on both sides of the Pend d'Oreille River at the boundary and on the east side of the river for 800 feet north of the boundary. The breccia is composed of angular and poorly rounded fragments of dolomite less than three-quarters of an inch across in a matrix of very finely crushed dolomite. The dominant colour of the breccia is light grey, and both fragments and matrix may be white, grey, or black. Irregular dark-grey lenses and bands a few feet thick cross the breccia, and small faults with polished and striated surfaces offset the bands. The small faults appear to have no consistent pattern of orientation or offset. The attitude of the Monument fault is uncertain. The western contact of the Nelway formation is probably along the fault and can be located as far north as Slate Creek, but north along the creek and south of the boundary there are no outcrops close to the projected position of the fault. South of the boundary the fault has been projected across a covered area (*see* Dings, 1956) to join a steeply dipping fault downthrown on the west.

The contact of the Nelway formation with the Active formation between the Pend d'Oreille River and Russian Creek is regarded as a fault. It has been traced from the International Boundary near Russian Creek to the Pend d'Oreille River but has not been located north of the river. Extreme contortion and shearing of the Active argillite on the north side of the river and along the Nelway–Waneta road make it difficult to locate a single fault zone even though the rocks are well exposed. South of the boundary the contact is referred to as the Day fault (*see* Dings, 1956) and is poorly exposed. Evidence that the contact is a fault is based on exposures in prospecting trenches on the west side of Russian Creek about 700 feet north of the boundary. The fault strikes northeast parallel to banding in the upper Nelway limestone and to cleavage in the Active formation; it probably dips steeply.

Too few data are available to explain the relationships between the rock units and the three faults just described. Features of the two fault zones east of the Day fault suggest that they are transverse faults of the same type as those at the Reeves MacDonald mine. Rocks on either side of the Day fault are in the same structural relationship as those on either side of the Black Bluff fault, which has not been identified southwest of Shenango Canyon. Whether or not the Day and Black Bluff faults are parts of the same zone is a matter for speculation (*see* p. 58).

STYX CREEK FAULT

The Styx Creek fault crosses the International Boundary in a prominent valley at the head of Billy Creek and takes its name from Styx Creek in the Metaline quadrangle (*see* Dings, 1956). The fault is downthrown on the east, bringing the Reeves limestone into contact with the middle dolomite of the Nelway formation. Estimates of the displacement depend on the plunge and position of the axis of the Sheep Creek anticline. Matching of the top of the Reeves limestone on the west side of the fault with the same horizon east of the fault, as projected from south of the South Salmo River, indicates a vertical displacement of between 4,500 and 6,500 feet. The fault is not exposed and can be located with assurance only at the head of Billy Creek and east of the upper part of Eldorado Creek. The displacement appears to be less near Eldorado Creek than along Billy Creek and probably diminishes to the northwest. Offset of the Black Bluff fault east of Rosebud Lake is probably only slight.

RIPPLE CREEK FAULT

The Ripple Creek fault, and several subsidiary faults south of it, cross the Sheep Creek anticline on the north side of the South Salmo River. The main fault can be traced from the Sheep Creek anticline eastward beyond the map-area across Stagleap Creek and along Ripple Creek to the International Boundary (*see* Little, 1950). The fault is assumed to extend west from the anticline and to offset the Black Bluff fault, but the trace is largely concealed by a gravel terrace along the South Salmo River. On the south slope of Lost Mountain a prominent depression with a steep scarp on the north side marks the main fault, and well-defined lineaments follow the subsidiary faults. The fault planes are not exposed, but, judging from the straight traces and the attitudes of small faults close to the large ones, all the faults dip steeply. Quartzites near the Ripple Creek fault are highly fractured, and at a few places limestones contain coarse breccia zones. An approximate measure of the displacement on the Ripple Creek fault and subsidiary faults south of it has been obtained by matching cross-sections of the Sheep Creek anticline on either side of the faults. The vertical displacement of the Ripple Creek fault is estimated to be about 2,500 feet and the horizontal displacement about 1,000 feet, the south side having moved down and to the west in relation to the north side. The largest subsidiary fault, immediately north of the South Salmo River, is estimated to have a vertical displacement of about 1,000 feet and a small horizontal displacement, and to be downthrown on the north. Away from the Sheep Creek anticline the displacement on the Ripple Creek fault has not been determined. To the west the offset appears to diminish because the fault cannot be recognized with certainty. To the east the offset of steeply dipping beds is much greater than it is on the Sheep Creek anticline (*see* Little, 1950). It is concluded that the displacement increases for some distance east of the anticline and possibly that the fault is hinged a short distance west of the anticline.*

IRON MOUNTAIN FAULT

The Iron Mountain fault is a steeply dipping northerly striking fault that forms the west side of the Black Argillite Belt from Truman Hill to the northeast side of Iron Mountain. On the east side of Truman Hill it is covered by talus. To the north the fault can be traced down the south slope of Lost Creek, where it forms the contact between the Reno quartzite on the west and the Active argillite on the east. The fault is covered by a wide gravel terrace along the north side of Lost Creek, north of which it brings the Active argillite into contact with quartzite of the Lower Navada member. The fault is intruded by the south end of the Emerald stock and is offset to the right by the Granite fault (*see* p. 113) near the Jersey townsite. North of the Granite fault the

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* A previous interpretation that the Ripple Creek fault is a tear fault related to deformation that formed the Sheep Creek anticline (*see* Little, 1950, p. 32) has not found support in the present more detailed study.

Iron Mountain fault is not exposed but can be located readily as far as the Dodger stock, north of which it has not been recognized. From its surface trace on the south side of Lost Creek, the fault appears to dip steeply. Diamond drilling north of the Granite fault indicates that at the south end of the Jersey mine the Iron Mountain fault dips less than 45 degrees west. Farther north the surface trace suggests a steep dip, and drilling from the Dodger 4200 crosscut (*see* Fig. 9) shows that the fault dips steeply near surface and dips west at depth. Drill cores that pass through the fault near the south end of the Jersey mine show several tens of feet of brecciated black argillite and small amounts of brecciated limestone near the fault. The amount of vertical displacement, estimated from the position of the base of the Reeves limestone on either side of the fault south of Lost Creek, appears to be not less than 1,000 feet down on the east side. The estimate is complicated by a northwesterly striking fault that offsets the Iron Mountain fault and is probably downthrown on the northeast. The Iron Mountain fault is pregranite and is younger than the Argillite fault.

FAULTS ALONG THE SALMO VALLEY

Near the Salmo Valley, faults have been mapped west of Woodchuck Creek (*see* Fig. 2). They strike north, dip steeply, and cut the granitic rocks. One fault can be traced south across Sheep Creek, where it probably forms the eastern contact of the granitic stock east of the Salmo Valley. These faults are the only ones that have been observed near the Salmo Valley, but a fault or a series of faults is assumed to follow the valley from Shenango Canyon to near the mouth of Sheep Creek. South of Sheep Creek the Waneta fault appears to be offset along the Salmo Valley. Between Swift Creek and Creggan Creek, Active argillite on the east side of the valley, unaffected by thermal metamorphism, contrasts with granite and granitized rocks on the west, and neither structures nor rock types can be projected across the valley. The Argillite fault is clearly recognized near Shenango Canyon and south of the mouth of the South Salmo River, and appears to be offset along Salmo Valley. These features are taken as evidence that a postgranite fault or series of faults referred to as the Salmo Valley fault follows the valley. Near Shenango Canyon the Salmo Valley fault probably curves to the southwest and continues beneath cover as far as Slate Creek. Possibly the Day fault (*see* p. 61) south of the Pend d'Oreille River is the southwesterly continuation of the Salmo Valley fault. Estimates of displacement on the Salmo Valley fault are speculative. The Argillite fault is offset from near Shenango Canyon to south of the South Salmo River, a distance of about 3 miles. The two faults are nearly parallel, and the relatively large offset on the Salmo Valley fault does not necessarily indicate a large displacement. The Black Bluff fault is probably offset in the same way as the Argillite fault (*see* p. 58).

STRUCTURE OF THE MINE BELT

Isoclinal folds and bedding faults are the most important structures in the Mine Belt. Folds in the Mine Belt have been folded. The oldest folds recognized are mainly isoclinal, and are called primary. Folds superimposed on them are called secondary. Early bedding faults probably originated as thrusts during the primary folding, and movement continued on them through most of the secondary folding. Primary and secondary structures are locally warped by late cross-folds. Transverse faults offset all these structures. Some are later and some earlier than the granitic rocks.

The structure along the south and east sides of the Mine Belt is more completely known than that on the north and west sides, mainly because the stratigraphy is best known along the south and east sides of the belt. In the central and southern parts of the Mine Belt, phyllites with no distinctive markers underlie most of the north and west sides of the belt. In the Porcupine Creek area rocks on the western side of the belt have been deformed and metamorphosed to such an extent that determination of their structure is virtually impossible.

For descriptive purposes the Mine Belt has been divided longitudinally into three parts: (1) A southern part extending from Waneta to Shenango Canyon, (2) a central part from the South Salmo River to the Hidden Creek stock, and (3) a northern part in the Porcupine Creek area. Granitization in the area north of Shenango Canyon and extensive cover along the Salmo Valley prevent individual structures in the southern part from being linked with those of the central part. The Hidden Creek stock isolates the northern part of the Mine Belt from the central part.

The structure of the southern part of the Mine Belt is dominated by the Salmo River anticline, that of the central part by the Jersey anticline, and that of the northern part by the Jack Pot anticline. These structures all lie on the south and east sides of the belt but are not regarded as parts of the same anticline.

SOUTHERN PART

The most prominent structure in the southern part of the Mine Belt is an overturned isoclinal anticline named the Salmo River anticline. It has been traced from Shenango Canyon to Church Creek, a distance of more than 7 miles. Quartzites of the Quartzite Range and Reno formations are exposed at the core of the anticline, and the Truman member, Reeves limestone, and Emerald argillite are repeated on the limbs. Both limbs are exposed between Shenango Canyon and the ridge east of Harcourt Creek, but west of Harcourt Creek the south limb is concealed beneath the Argillite fault. The axial plane of the anticline strikes east and dips 40 to 60 degrees south. The axis is thought to be nearly horizontal because the limbs have a nearly parallel surface trace over a strike length of 4 miles. Dragfolds or lineations that might give some measure of the plunge of the anticline have not been found.

Dragfolds related to secondary structures are common throughout the southern part of the Mine Belt. They range in size from small folds seen in individual outcrops to large ones determined only by mapping, and they range in attenuation from gentle flexures to dragfolds with an overlap of several times the thickness of the beds involved. Dragfolds plunge between south and southwest at angles mainly between 45 and 55 degrees and with very few exceptions are Z-shaped in plan (*see* p. 50). These folds are Z-shaped on either limb of the Salmo River anticline, and hence they are not related to the development of the anticline. They indicate a relative movement of the south side of the area westward. Detailed mapping reveals that some structures of this type are large. The Reeves limestone on the south limb of the Salmo River anticline thins from a thickness of 600 feet near the Pend d'Oreille River to nothing about 8,000 feet east of the river. Surface mapping and underground data at the Reeves MacDonald mine (*see* Fig. 18) show that this thinning is the result of the "tailing out" of a secondary, attenuated isoclinal syncline in the Reeves limestone known as the Reeves syncline that plunges south 35 degrees west at 55 degrees. The Truman member occurs on both limbs of the syncline and is remarkably infolded with the Reeves limestone at the trough (*see* Plate XII). On the south the syncline is truncated acutely by a bedding fault.

The Nugget quartzite at the core of the Salmo River anticline ends a few hundred feet north of the Reeves MacDonald mine in two masses that may be parts of a large Z-shaped dragfold (*see* Fig. 3). Lineations and small dragfolds around the western end of the southern mass plunge 45 to 50 degrees southwest, and it is almost certain that the quartzite ends along a similar plunge. About 4,000 feet east of these two masses the Nugget quartzite is folded into a series of large steeply plunging Z-shaped folds, and it seems likely that the two masses just described are parts of a similar dragfold.

West of the Pend d'Oreille River and north of the Red Bird prospect a large steeply plunging Z-shaped dragfold is outlined by the contact between the Reno and Navada quartzites. The fold has a number of peculiarities. The Upper Navada white quartzite, a bed about 50 feet thick, appears to pinch out in the section of the fold striking northward. The quartzite can be traced west from the Red Bird trail (*see* Fig. 3) to a point where it curves abruptly north and ends. Several hundred feet farther to the north the quartzite reappears and continues as a prominent band in bluffs to the west (*see* Plate V). The Reno quartzite south of the Navada quartzite is contorted by many small dragfolds plunging south 20 to 30 degrees west at about 45 degrees. The overlying Truman member does not follow round the major dragfold, and so the Reno quartzite is much thicker west of the fold than it is to the east. The structure of the Reeves limestone at the Red Bird prospect is not known, but abundant micaceous layers in the limestone probably represent isoclinal infolds of Truman phyllite. Much of the folding of the quartzite appears to have been taken up by shearing at the base of the limestone or in the Truman member.

West of the Pend d'Oreille River, on the overturned limb of the Salmo River anticline, an attenuated anticline involving the Truman member and the Upper Reno quartzite has been traced from the river to above the Red Bird trail. Dragfolds in Reno quartzite near the crest of the anticline plunge south 35 degrees west at 40 degrees, and a large dragfold on one limb of the anticline exposed on the west bank of the Pend d'Oreille River plunges south 35 degrees west at 55 degrees. The anticline is incomplete and is faulted on the south limb.

The symmetry of the Salmo River anticline is broken by bedding faults, some of which have been traced for more than 2 miles. At single points of observation the faults are bedded, but when mapped in detail they are found to transgress rock units along strike. Although little is known about the faults at depth, it is probable that they transgress rock units down dip as well as along strike. The faults are recognized from stratigraphic evidence and from the tracing of contacts. One of the most prominent faults is on the northern, overturned limb of the Salmo River anticline. On the south side of the Salmo River canyon between the mouths of Wallack and McCormick Creeks, this bedding fault is on the south side of the Reeves limestone. Through much of its length it brings the limestone into contact with Reno quartzite. To the west it passes stratigraphically lower into the Reno quartzite until, about 1,000 feet east of the O'Donnell fault, it brings the limestone into contact with the underlying Navada quartzite. West of the O'Donnell and B.L. faults a similar bedding fault separates the Reno quartzite from the Nugget and, farther west, from the Navada quartzite. Diagrammatic reconstruction of the blocks offset by the B.L. and O'Donnell transverse faults (*see* p. 60) suggests that the bedding fault on the south side of the Reeves limestone east of the transverse faults and that on the south side of the Reno quartzite west of the transverse faults may be parts of the same bedding fault. If this is so, the bedding fault dips more gently south than do the adjacent rock units.

West of the Pend d'Oreille River a bedding fault on the overturned limb of the Salmo River anticline separates Reno quartzite and phyllite of the Truman member from Navada quartzite on the south. To the west the fault brings the Navada quartzite into contact with the overturned Reeves limestone and, farther west, at the head of Harcourt Creek, Reno quartzite on the right-side-up limb of the Salmo River anticline is in contact with the overturned Reeves limestone. Throughout the length of the Salmo River anticline the limestone on the overturned limb is continuous and is not involved in large steeply plunging folds. It is significant that this limestone, which contains no steeply plunging folds, is separated by a bedding fault from rocks to the south which contain a number of large steeply plunging folds.

Another bedding fault is recognized on the southern limb of the Salmo River anticline at the Reeves MacDonald mine. It lies between Emerald black phyllite and schist and limestone of the Truman member, on the south side of the steeply plunging syncline of Reeves limestone at the Reeves MacDonald mine (*see* Fig. 18). On surface the Emerald member appears to be in normal contact with the Reeves limestone, but underground and in drill core 20 to 100 feet of phyllite and limestone of the Truman member lie south of the Reeves limestone. Where seen underground the contact is followed by a lamprophyre dyke, but intense shearing on each side of the dyke confirms the stratigraphic evidence of a faulted contact. Similar relationships continue as far as the east side of the O'Donnell fault. Farther east, in an area of scanty outcrop, the Emerald member appears to be in contact with quartzites and the fault probably continues eastward, although it has not been identified near Shenango Canyon. The fault has not been found west of the Pend d'Oreille River.

No measure of displacement on the bedding faults has been possible. Because of the close association between the faults and primary isoclinal folds, it is thought that the faults originated during the primary folding. From the fact that the faults have been only slightly folded it is concluded that movement continued on them during the secondary folding. In the period of primary folding dip slip was probably dominant. In the southern part of the Mine Belt the close relationship between the faults and the steeply plunging secondary folds suggests that during the secondary folding displacement was largely strike slip, the south side moving westward in relation to the north.

The Salmo River anticline is an exceedingly complex structure, the true form of which cannot be determined. The simplified plan of Figure 4a shows diagrammatically the main structural elements of the anticline and the primary folds between it and the Argillite fault. The diagram emphasizes the lack of symmetry across the axis of the anticline and the near parallelism between many of the bedding faults and formational contacts. The resultant rock sequence is apparently homoclinal, and for many practical purposes may be regarded as such. Only detailed knowledge of the stratigraphy and close mapping of relatively large areas reveals the presence of the anticline.

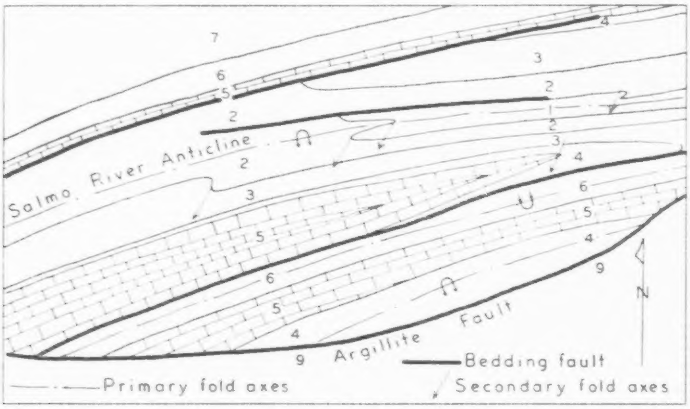

Figure 4a. Diagrammatic plan showing the main structural elements of the Salmo River anticline. Formation numbers are the same as those used in Figure 3.

The present form of the Salmo River anticline has been reached by interbed slippage, extreme attenuation, and shearing. The anticline and other primary folds cannot actually be seen, and no measure of the intensity of the primary deformation is to be found. Primary structures have been greatly modified in the secondary deformation. Some indication of the intensity of the secondary deformation is illustrated by a series of secondary folds exposed in the Reeves MacDonald mine, one of which is shown in Plate XII.

Structures north and south of the Salmo River anticline are not well known, but the structural pattern seen on the anticline extends through most of the southern part of the Mine Belt. Along the Pend d'Oreille River south of the Reeves MacDonald mine a prominent band of limestone followed to the south by interbanded schist and limestone outcrops north of the Argillite fault. The whole sequence dips 45 to 60 degrees southward and appears to be homoclinal. The rock units are difficult to recognize because of dolomitization and silicification of the limestone and strong shearing of the micaceous rocks, but it is almost certain that the limestone and dolomite are the Reeves member and that the schist with interbanded limestone is the Truman member with infolds of the Reeves. It is believed that these rocks are on the overturned south limb of a syncline, which is cut off to the north by a bedding fault along the north side of the Emerald phyllite (*see* Fig. 17) and to the south by the Argillite fault. West of the Pend d'Oreille River outcrops are scarce, but the syncline is probably truncated by the Argillite fault south of the Red Bird prospect. The structure continues eastward into the area east of the O'Donnell fault but has not been recognized near Shenango Canyon.

North of the Salmo River on either side of McCormick Creek, a few details of the structure are known from exposures of Navada and Reno quartzite and Reeves limestone, but most details are not known. Rocks along the Salmo River, between the Reeves limestone on the overturned limb of the Salmo River anticline and the quartzite on McCormick Creek, are phyllites of the Emerald member and Upper Laib. In general, they dip southward and appear to occupy an overturned isoclinal syncline with low plunge. Many of the rocks are strongly sheared, and steeply plunging dragfolds are common, so it is probable that the syncline is greatly modified by steeply plunging structures and its recognition is of little significance. Similarly to the north, the appearance of the Reeves limestone and Reno and Navada quartzites at the surface east and west of McCormick Creek probably indicates the presence of a primary, gently plunging anticline, but bedding faults, steeply plunging dragfolds, and related shears and bulges dominate the structure. The geology in this area, shown on Figure 3, Sheet B, is a simplification, particularly on the west side of McCormick Creek.

An overturned southward-dipping sequence comprising Lower and Upper Navada and Reno quartzite is exposed in the canyon and east side of McCormick Creek. On the south this sequence is in bedding fault contact with black phyllite of the Upper Laib or the Emerald member. To the north it is in contact with Reeves limestone, and this contact may also be a bedding fault as the Truman phyllite is missing. The Reeves limestone is abnormally thin, contains wisps and beds of grey and black phyllite, and is in contact on the north with a relatively thick sequence of black phyllite and argillite. These facts suggest that the limestone, like the quartzite, is overturned and the lower part of the member may be missing. The same sequence of black phyllite, quartzite, and limestone occurs at the Red Rock property to the northeast and is probably offset northward on a transverse fault. The units are thinner than they are at McCormick Creek, but the structure appears to be the same.

The complex relationships west of McCormick Creek have not been resolved. The limestone which forms open bluffs west of the sawmill near McCormick Creek (*see* Fig. 3) dips south and is overlain by black phyllite, probably belonging to the Emerald member. It has not been satisfactorily traced east to McCormick Creek. To the west it thins rapidly and is in contact on the north with quartzite belonging to the Navada member. The quartzite does not extend eastward to McCormick Creek and is separated from a thick section of black phyllite to the north by a thin band of limestone resembling that of the Reeves member. No limestone or quartzite of this sequence has been found more than 4,000 feet west of McCormick Creek. The distribution of rock types and the presence of many steep southwestward-plunging dragfolds and lineations suggest that the dominant structure is a steeply plunging one. In the development of this structure, probably by relative movement of the south side of the area westward, the rocks have been sheared to such an extent that most contacts are faults and many details of the structure are incomprehensible.

Along the Pend d'Oreille River west of the mouth of the Salmo River, the structure is essentially unknown. With the exception of the area just described, the rocks between McCormick and Harcourt Creeks form a south- and southeastward-dipping sequence of phyllites containing no distinctive lithologic units that might be traced or correlated from place to place to indicate the structure. Many shear zones and attenuated steeply plunging dragfolds are well displayed along the Pend d'Oreille River, and these and a prominent, steeply plunging lineation shown by many of the phyllites east of the river indicate that the structural pattern is similar to that found elsewhere in the southern part of the Mine Belt. Though the sequence appears homoclinal, there can be little doubt that it contains large and complex gently and steeply plunging isoclinal folds and bedding faults which have not been recognized.

Thinly banded cherty quartzites of unknown correlation which form the canyon on the Pend d'Oreille River at the mouth of Harcourt Creek have been traced eastward to Limpid Creek and west to Fraser Creek. These and other distinctive rock units to the northwest, which can also be followed for relatively great distances along the strike, form a south- and southeastward-dipping homoclinal sequence in which a few steeply plunging folds have been seen. The structure probably includes isoclinal folds and bedding faults, although none has been recognized. These rock units probably do not belong to the Laib formation (*see* p. 37), and it is believed that a bedding fault exists between them and those of the Upper Laib to the south and southeast. Studies in this area have not been detailed enough to establish whether or not the northern boundary of the Laib formation as shown on Figure 3 represents a major fault.

CENTRAL PART

The Mine Belt between the South Salmo River and the Hidden Creek stock is dominated by a complex isoclinal anticline named the Jersey anticline. The anticlinal axis strikes about north 15 degrees east and plunges gently both northward and southward. The plunge is as much as 30 degrees to the south on the South Salmo River and on Truman Hill, but it decreases northward to horizontal near the top of Iron Mountain and the northern side of the Salmo River monzonite stock. On the northern slopes of Iron Mountain the plunge is northward and is locally as steep as 45 degrees. Between Sheep Creek and the Hidden Creek stock the plunge is again to the south, at angles between 15 and 20 degrees.

The anticline is overturned; the axial plane dips steeply east on the eastern side of the Mine Belt and flattens to the west until the anticline is recumbent. Very little is known about the exact shape of the anticline because only parts of it are exposed and its form has been modified by secondary structures. The right-side-up eastern limb appears to have ridden over the overturned limb on a series of bedding faults. The fold has been folded into secondary open anticlines and synclines. Structural continuity is broken by transverse faults and to a minor extent by the Emerald and Salmo River stocks.

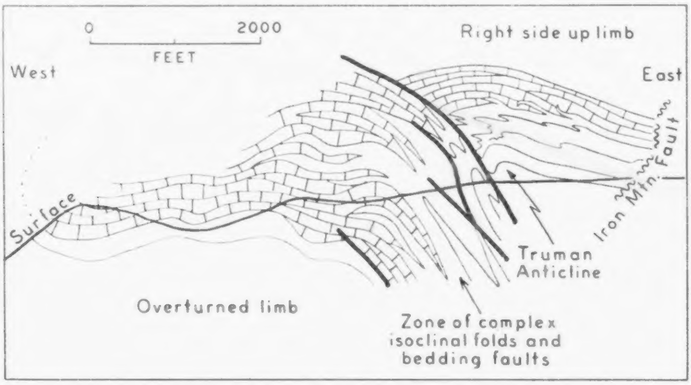

Figure 4b. Diagrammatic section of the Jersey anticline on the south slope of Iron Mountain.

The Jersey anticline has been recognized from a knowledge of the stratigraphic sequence and from application of this knowledge in extensive detailed mapping. Evidence for the existence of the fold, and for the interpretation that it is a primary fold modified by secondary folds, is most complete between the South Salmo River and the northern slope of Iron Mountain. Farther north the overturned limb can be recognized, but the general form of the anticline is obscured by complex local structures and by the fact that part of it has been cut out by the Argillite fault. For descriptive purposes the Jersey anticline will be considered in three parts: (*a*) The right-side-up or normal limb, (*b*) the overturned limb, and (*c*) the central zone of complex isoclinal folds and bedding faults between the two limbs (*see* Fig. 4b).

(*a*) *The right-side-up limb* of the Jersey anticline forms the upper part of Iron Mountain and most of Truman Hill. The Reeves limestone capping both Iron Mountain and Truman Hill is the highest stratigraphic unit in a right-side-up sequence in which rocks as old as the Quartzite Range formation are exposed at various places. This sequence is well displayed on the northwest slopes of Truman Hill, and the upper part of it can be seen underground in the Jersey and Dodger mines. On the right-side-up limb the rocks dip generally less than 50 degrees, commonly to the east or south and less commonly to the west. Locally the rocks are contorted, and close studies on Iron Mountain reveal a pattern of intricate complex dragfolds (*see* p. 112). Despite complexities of detail, the right-side-up limb as a whole appears to be gently folded and the over-all outline is simple.

The exact relationship of the right-side-up limb of the Jersey anticline to the overturned limb and to the central zone of complex folds is not known because the anticline has been disrupted by faulting. The only exposed cross-section of the right-side-up limb is on the northwest slope of Truman Hill. At this locality (*see* Plate IV) the rocks dip uniformly 35 to 45 degrees southeastward. To the southwest they become contorted, and a series of relatively open southward-plunging dragfolds curve around the axis of a subsidiary anticline, the Truman anticline, which occupies the western slopes of Truman Hill. Only the upper part of the axial zone of this anticline is exposed, and so the shape of the fold is not known, but dragfolds in the Reno and Upper Navada quartzites in the upper part of the axial zone indicate that the fold is strongly overturned. The western limb of the Truman anticline is broken by a poorly exposed bedding fault separating the Truman anticline from the central complex zone of the Jersey anticline. The Truman anticline and the bedding fault along its western limb probably continue northward along the Quartzite Ridge north of Lost Creek until they are cut by the transverse Granite fault near the Jersey mine (*see* Fig. 9). North of the Granite fault, along the steep western slopes of Iron Mountain, the right-side-up limb of the Jersey anticline appears to bear a normal unbroken relationship to the zone of complex isoclinal folds, but details of the structure in this area are imperfectly known because no cross-sections are exposed.

(*b*) *The overturned limb* of the Jersey anticline is well exposed at many places, from near the mouth of the South Salmo River to the Hidden Creek stock at the head of Aspen Creek. For more than a mile north of the mouth of the South Salmo River the Reeves limestone forms bluffs on the eastern side of the Salmo Valley. The limestone dips gently eastward and southward and lies above black argillite of the Emerald member, which in turn is above a thick sequence of phyllites and micaceous quartzites of the Upper Laib formation. The sequence is stratigraphically overturned. The same sequence has been traced northeastward to the Emerald mine where, in addition to the Upper Laib, Emerald, and Reeves members, the Truman member and the upper part of the Reno quartzite occur in the overturned position. To the north parts of the same overturned sequence are exposed west of the Emerald road, west of the H.B. mine, along both sides of Aspen Creek north of the H.B. mine, and in an area of complex structure and granitic rock near the Aspen mine.

West of Iron Mountain between Sheep Creek and the South Salmo River the rocks dip gently and the overturned limb of the Jersey anticline is essentially recumbent. Toward the east the regional dip gradually steepens to about 45 degrees east.

Secondary folds in the recumbent part of the overturned limb are prominent, and primary, isoclinal folds are rarely seen. Secondary folds form a series of open asymmetric anticlines and synclines with amplitudes and distances between crests of several hundred feet (*see* Fig. 12). The axes of these folds strike between north 10 and north 20 degrees east. Near the South Salmo River they plunge as steeply as 35 degrees south, to the north they gradually flatten to horizontal, west of the Emerald mine and farther north they plunge gently northward. These secondary fold axes are essentially parallel to the primary fold axes. The secondary folds are outlined by banding in the Reeves limestone and by the attitude of formational contacts. They can be recognized also in rocks of the Upper Laib, but with difficulty, because, in addition to secondary folds, these rocks display small attenuated and disrupted isoclinal folds which are probably primary.

North of Sheep Creek very few details of the structure of the overturned limb are known because the rocks exposed contain no distinctive markers. The Reeves limestone and rocks close to it on the northern slope of Sheep Creek, west of the H.B. mine and along the east side of Aspen Creek, in general dip eastward at more than 45 degrees. The limestone is not repeated to the west, though the Upper Laib phyllites locally dip westward. The attitude of the foliation of the phyllites suggests that north of Sheep Creek the overturned limb has the same general form as it does south of Sheep Creek.

(*c*) *A zone of complex isoclinal folds and bedding faults* lies between the overturned and the right-side-up limb of the Jersey anticline. Detailed structures are fairly well known in parts of this zone but cannot be projected far along strike. The structures are displayed best on Iron Mountain and the slopes north of Lost Creek, and from studies in these areas the structural pattern has been worked out. Despite adequate exposures of rock on the southwest slope of Iron Mountain, reconstruction of folds requires considerable interpretation because fold axes plunge nearly parallel to the slope of the hill.

A small area east of Lime Creek and north of the gravel terrace along the north side of Lost Creek gives the most complete cross-section of the zone of isoclinal folds between the overturned and the right-side-up limb of the Jersey anticline. In this area the folds plunge between 30 and 35 degrees south, steeper than the slope of the hill, so that a map is in effect an oblique cross-section (*see* Fig. 5). Detailed mapping reveals isoclinal anticlinal tails of argillite of the Truman member and synclinal tails of the lower part of the Reeves limestone secondarily folded into relatively open anticlines and synclines.

In the area shown in Figure 5 the argillite is mainly siliceous, fine grained, and well banded. It occurs as bands as much as 200 feet wide which can be traced around the crests and troughs of relatively open folds and which tail out systematically to the west. Bands of limestone separate those of argillite and can be traced around the same open folds, but the limestones tail out systematically to the east. Each tail of argillite is regarded as an isoclinal anticline, and the intervening tail of limestone as a corresponding isoclinal syncline. Banding in the limestone and argillite outlines the open, secondary folds but does not reveal the existence of the isoclinal, primary folds. Primary folds are extremely attenuated and sharp crested; primary isoclinal anticlines are revealed by individual tails of argillite which have the form of slender curving wedges.

These rocks near Lime Creek are truncated on the northeast by a northwesterly trending fault and are separated from the extensive rock exposures west of the Quartzite Ridge (*see* Fig. 9) by an area of poor outcrop. Hence the isoclinal folds outlined in cross-section near Lime Creek cannot be traced directly to the zone of isoclinal folds in the area west of the Quartzite Ridge that extends northward to the northwest slope of Iron Mountain. In this area no well-exposed cross-sections are seen, and isoclinal

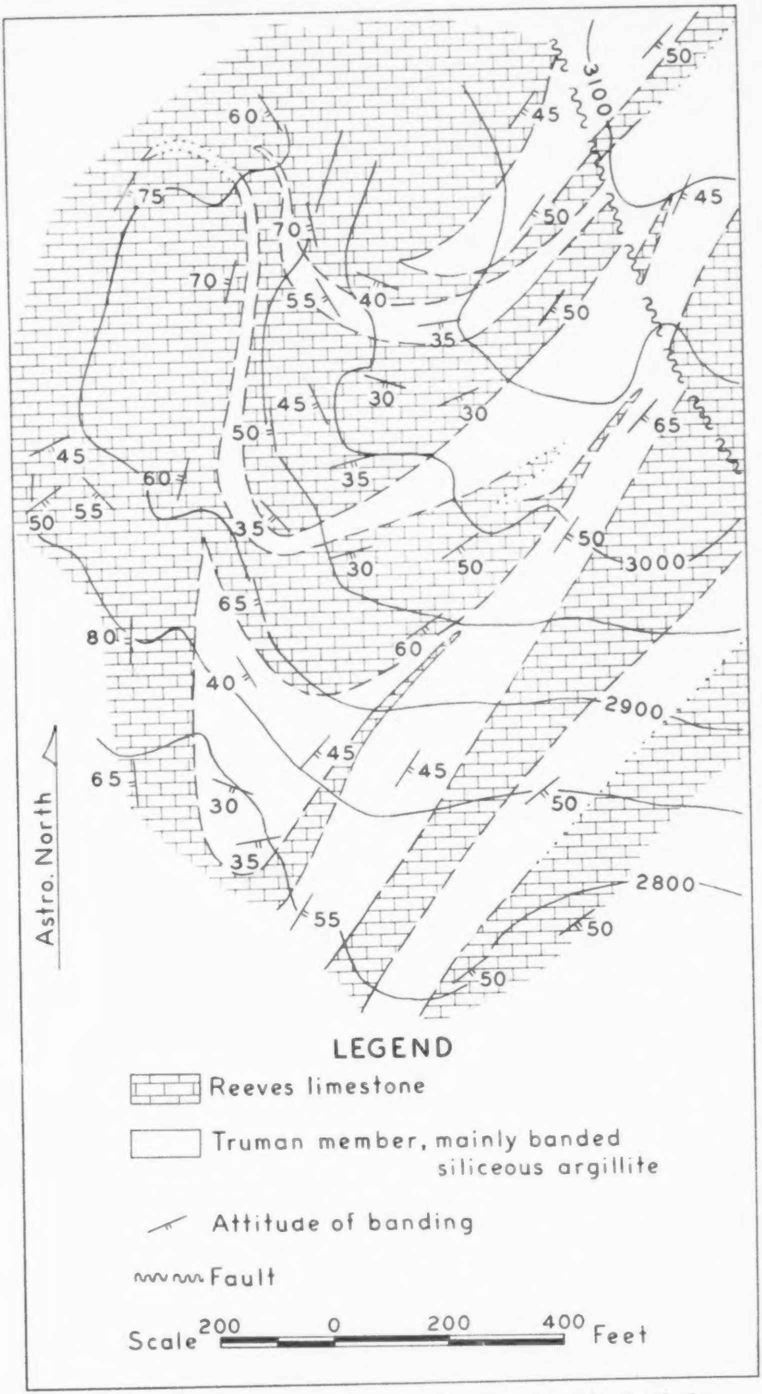
Astro. North
3100
3000
2900
2800
LEGEND
Reeves limestone
Truman member, mainly banded siliceous argillite
Attitude of banding
Fault
Scale 200 0 200 400 Feet

Figure 5. Map showing folded folds in the zone of complex isoclinal folds near the core of the Jersey anticline.

folds are recognized only from stratigraphic relationships. West of the top of Iron Mountain the axes of the folds are horizontal, to the north they plunge gently northward, and to the south they plunge southward as steeply as 20 degrees, somewhat steeper than the slope of the hill. In general, axial planes of the folds strike about north 20 degrees east and dip between 50 and 70 degrees eastward. West of the Quartzite Ridge, axial planes traced southward swing to the southwest in strike and flatten in dip. South of the Emerald stock the upper part of the Reno quartzite is exposed in the core of two isoclinal anticlines. The intervening syncline contains argillite, skarn, and limestone of the Truman and lower part of the Reeves member. The quartzite plunges beneath the surface west of the Quartzite Ridge, and toward the south first the Truman argillite and then the Reeves limestone becomes the dominant rock exposed. North of the Emerald stock the lower part of the Reeves limestone occurs in troughs of isoclinal synclines, and rocks of the Truman member form the crests of intervening anticlines. These structures can be traced northward to the Dodger stock and the drift-covered area on the northern slope of Iron Mountain.

South of Annie Rooney Creek and east of the Emerald road, in an area of limited outcrop, fold axes plunge 30 to 50 degrees northward and, in general, foliation dips to the north or east. On the south side of this area a sequence including Emerald black argillite, Reeves limestone, Truman brown argillite and the upper part of the Reno quartzite dips northward, faces south, and appears to be part of the overturned limb of the Jersey anticline. To the north, complexly folded brown argillite, skarny argillite, and limestone belonging to the Truman and lower part of the Reeves members occur in a series of isoclinal folds near what is probably the axial zone of the Jersey anticline. Outcrops are not extensive enough to outline the details, but close mapping suggests a pattern of folded folds similar to that east of Lime Creek (*see* p. 70).

From the foregoing descriptions it is apparent that the Jersey anticline is an exceedingly complex structure which contains many subsidiary folds and is broken by many faults. Parts of the anticline are seen at various places, and nowhere is a complete cross-section well exposed. The diagrammatic section of Figure 4b across the southern slopes of Iron Mountain is an attempt to integrate what is known of the structure. The fold is nappe-like. In the recumbent part only the overturned limb is exposed and reconstruction of the part above the overturned limb is not possible. The relationship of the right-side-up limb to the complex isoclinal folds to the west is obscure at many places in the field (*see* p. 69), but the diagram emphasizes the existence of a fault or a zone of bedding and thrust faults between these two parts of the anticline. The fault zone is exposed in a number of places, although it has not been found in others.

North of Annie Rooney Creek the Jersey anticline cannot be recognized as such. The overturned limb continues northward to the south side of the Hidden Creek stock, but between the Reeves limestone on the overturned limb and the Argillite fault to the east no over-all anticlinal structure is apparent. In this interval the upper part of the Reno quartzite, the Truman argillite, and the Reeves limestone are repeated several times in what appears to be a homoclinal sequence but is in fact a series of isoclinal folds broken by bedding faults. The folds plunge gently southward, and the bedding faults in general dip eastward.

On the lower slopes north and south of Sheep Creek a relatively sharp cross-fold has warped the axial planes and reversed the plunge of the older folds. North of Sheep Creek the cross-fold plunges steeply northeast. Bedding faults have been folded, and the cross-fold is considered to be later than secondary structures. Similar cross-folds are found near the southern margin of the Hidden Creek stock.

Bedding faults are common in the central part of the Jersey anticline. Several are exposed, but in single outcrops they do not in general resemble faults, probably because they were originally bedded shear zones which subsequently were obscured by thermal metamorphism. They are referred to as bedding faults even though locally they transect beds abruptly. Recognition of the faults is based on stratigraphic evidence and the detailed tracing of contacts.

The Jersey fault (*see* Fig. 9) follows the west side of the Quartzite Ridge south of the Jersey townsite and has been traced north to the Emerald stock. In trenches at the south end of the Quartzite Ridge the fault strikes north 10 degrees east and dips steeply. It separates gently dipping limestone and dolomite on the west from micaceous quartzite on the east. The fault zone contains lenses of skarn and minor sulphides. Along the greater part of the west side of the Quartzite Ridge the rocks dip east, limestone west of the fault is right-side-up, and quartzite east of the fault is overturned. Along strike the fault gradually truncates rock units and primary folds. The fault is crossed by the Jersey 4200 crosscut (*see* Fig. 9) close to the west side of the Emerald stock. Projection of the fault to surface from the crosscut indicates that the fault dips less than 30 degrees east.

The Jersey fault is typical of other bedding faults in the area between the South Salmo River and the Hidden Creek stock. Some others are described in detail in Chapter V. Displacement has not been determined on any of the faults, but it is generally assumed that they are thrust faults on which the movement was dominantly dip slip. The faults transact primary isoclinal folds and are therefore later than the folds. Some of the bedding faults also transact secondary folds (*see* Fig. 10), but others have been folded during the period of secondary folding. Bedding faults are folded in zones of late cross-folding, such as that near Sheep Creek south of the H.B. mine; these cross-folds are probably later than the secondary folds.

PORCUPINE CREEK AREA

The structure of the Mine Belt north of the Hidden Creek stock is more complicated and less well known than it is to the south. The structural pattern is the same, but bedding faults are more numerous and metamorphism is more widespread and more intense. In Figure 3, sheet C, only those bedding faults are shown that are well known from stratigraphic and structural evidence. Other bedding faults undoubtedly exist, although they have not been recognized or located with certainty.

The largest fold recognized is a complex isoclinal anticline named the Jack Pot anticline exposed on both sides of Porcupine Creek a short distance west of the switchback roads to the Jack Pot and Oxide properties. The axial plane of the anticline strikes slightly east of north and dips less than 30 degrees east at low elevations and more than 45 degrees at higher elevations. The axes of dragfolds, which are probably parallel to the axis of the main anticline, plunge 5 to 15 degrees south. The anticline is highly attenuated on the south side of Porcupine Creek. The attenuation is shown by Nugget quartzite, which tapers gradually in the core of the anticline and ends at about 4,000 feet elevation. On the north side of Porcupine Creek the Nugget quartzite at the core ends abruptly and the anticline may not be as attenuated as it is to the south. On the western or overturned limb a bedding fault follows the eastern side of the Reeves limestone. The fault brings the limestone into contact with the lower part of the Reno formation on the south side of Porcupine Creek, and into contact with various parts of the Lower Navada member on the north side of the creek. Two highly attenuated anticlinal " tails " of limestone occur on the west side of the Reeves member and appear to represent primary dragfolds on the overturned limb of the main anticline.

On the eastern limb of the anticline, Navada quartzite overlies the Nugget at the core. On the north side of Porcupine Creek the lower Navada quartzite appears to be in contact with the Reeves limestone, but outcrops are too scarce to determine whether or not the contact is a bedding fault. On the south side of Porcupine Creek the Navada member is abnormally thick and probably has been duplicated by isoclinal folds or bedding faults, though none has been traced in the field.

The Jack Pot anticline is followed on the east by a syncline named the Jack Pot syncline which is exposed on the south side of Porcupine Creek. The syncline is mainly in the Reeves limestone. The axial plane strikes east of north; above an elevation of about 4,500 feet it dips about 60 degrees east and below this elevation changes in dip through vertical to west. The form of the syncline is not known because an east-dipping bedding fault brings the limestone in the syncline into contact with quartzites of the Navada member and Reno formation. Rocks of the Truman member and part of the Reno formation occur on the eastern limb of the syncline and are in fault contact with the Active formation on the east side of the anticline, along the Argillite fault. The Jack Pot syncline has been followed underground for nearly 1,000 feet south of the most southerly surface exposures of limestone. It is truncated to the north by transverse faults and has not been recognized north of them.

South of Porcupine Creek above elevations of about 5,000 feet the structure is very complex, the rocks are partly granitized, and stratigraphic correlation has not been possible. The Jack Pot syncline and anticline cannot be recognized above elevations of about 5,000 feet. On top of the ridge the rocks in general dip gently south. Drift-covered areas prevent continuous tracing of beds from the northern slopes of the ridge where dips are steep to the top of the hill where dips are gentle. Detailed mapping of the Navada quartzite immediately west of the Jack Pot road shows that in going southward a gradual change in strike from south through southeast to east is accompanied by an increase in granitization of the quartzites. The relationship of the granitized quartzite to limestones on top of the hill is obscure, both near the road and to the west. Many contacts are faults, but it seems unlikely that a major thrust fault separates the steeply dipping structures on the north slope from gently dipping ones on top of the hill (*see* Little, 1950, Map 50-19A). No definite conclusions have been reached, but the favoured interpretation is that isoclinal folds and bedding faults change in attitude from steep east dips to gentle south dips in a complex warp superimposed on primary and secondary structures. It is a late cross-fold (*see* p. 47) probably related to emplacement of the Hidden Creek stock.

Very little is known of the structure and stratigraphy near the Oxide property north of Porcupine Creek and on the Last Chance claims north of Oscar Creek. The exposed rocks are black argillites and slates of the Active formation, grey limestone of uncertain correlation, and an assemblage of brown micaceous and white quartzite resembling the Lower Navada member of the Quartzite Range formation. Near the top, on the south side of the ridge between Oscar and Porcupine Creeks east of the road to the Oxide property, an asymmetric anticline involving quartzite, limestone, and Active argillite plunges at a low angle to the south. Farther south the plunge increases and becomes steeper than the slope of the hill. The limestone overlying the quartzite is intricately folded on the eastern limb and thinned on the western limb. West of the road the Active argillite is in fault contact with quartzite resembling the Lower Navada. The quartzite has a uniform steep easterly dip, but the fact that within it beds of white quartzite are discontinuous suggests that the rocks are isoclinally folded or are cut by bedding faults.

The structure of the western part of the Mine Belt on both sides of Porcupine Creek is essentially unknown. The structural pattern is probably the same as that to the east, but metamorphism, silicification (*see* p. 40), and a lack of marker beds make the actual structure very difficult to determine.

STRUCTURE OF THE BLACK ARGILLITE BELT

The Black Argillite Belt lies between the Mine Belt and the Eastern Belt, and contains mainly black argillite of the Active formation. The stratigraphy of the Active formation has not been determined and secondary structures within it are difficult to interpret, so that little is known of the over-all structure or of structural detail in the Black Argillite Belt. The structural pattern appears to be similar to that in the Mine

Belt, but individual structures are less regular and less continuous. Rocks of the Black Argillite Belt in general are less competent than those on either side, and appear to have responded more readily to deforming forces.

Between the South Salmo River and the Hidden Creek stock regional considerations suggest that the Black Argillite Belt occupies the trough of a major syncline flanked by older rocks in the Eastern and Mine Belts. During deformation a syncline may have formed, but if so it is now unrecognizable because of the bounding faults and the complexities of the internal structure.

Systematic studies of the structure of the Black Argillite Belt have not been made, but details are known at a few localities and distinctive markers have been traced over considerable distances (*see* Fig. 3). In the southern parts of the belt, on the hills at the heads of Church, Harcourt, and Red Bird Creeks, foliation dips south and southeast at angles generally less than 45 degrees. Locally, however, as at the head of Harcourt Creek, foliation dips northwest and dragfolds plunge gently to the south or southwest. Bedding and cleavage in the argillites are usually parallel, and northwesterly dips between elevations of 4,500 and 5,000 feet at the head of Harcourt Creek are taken to indicate that the southwesterly trending axis of an overturned anticline passes through this locality. Between the head of Red Bird Creek and Shenango Canyon dips are to the southeast, for the most part at angles greater than 45 degrees. A wedge of the Active formation along the Pend d'Oreille River just north of the International Boundary lies between two faults (*see* p. 61) and is complexly warped and sheared. A band of limestone and limy argillite within the formation has been traced from near the mouth of Slate Creek to the Nelway–Waneta road 500 feet above. At the river level the limestone dips west, and at higher elevations it passes through vertical to an easterly dip along the road. The changes in dip are accompanied by changes in strike from northeast on the river to north and back again to northeast on the road. This change in attitude involves a warping of attenuated isoclinal folds which can be seen in the limestone on the cliffs along the river.

Relatively detailed studies along the bluffs on the south side of the South Salmo River indicate a series of major isoclinal folds. Dragfolds plunge 25 to 35 degrees south or southwest, and both banding and cleavage in the argillite dip at moderate angles to the southeast. Isoclinal folds with amplitudes greater than 500 feet cannot be seen directly, but are indicated by alternating panels of rock in which dragfolds have opposing shapes. East of the H.B. mine on the north slope of Sheep Creek, detailed studies by geologists of The Consolidated Mining and Smelting Company of Canada, Limited (*see* Irvine, 1951) established a similar pattern of isoclinal folds. In this work the stratigraphic sequence could not be determined, but isoclinal folds were outlined by integration of dragfolds and the close tracing of beds. The dragfolds plunge gently south and the foliation dips steeply east.

In general, between the South Salmo River and the Hidden Creek stock, foliation in the Black Argillite Belt strikes north and dips steeply east. Distinctive rock units, mainly limy, have been traced for thousands of feet and maintain a fairly uniform attitude. Bedding and cleavage are usually parallel and are folded together. Although only a few isoclinal folds are known, it is probable that the pattern of isoclinal folding found east of the H.B. mine extends throughout the belt.

Although the regional dip is steeply east, relatively large areas are underlain by rocks with very gentle dip. Argillite on the summit and uppermost slopes of Nevada Mountain and dolomite (9c of Fig. 3) on the ridge between Billings and Bennett Creeks form the largest gently dipping masses. The significance of these dips and their relation to the regional steep dip has not been determined.

Although the strike of the foliation is generally north, it varies widely from place to place. In the bluffs on the south side of Lost Creek the strike is northeast, on the north side of Lost Creek it is north, and farther north on the northwest slope of Nevada Mountain it swings to as much as north 20 degrees west. North of Sheep Creek the strike swings from north, or slightly west of north, to northwest between the Sheep Creek stock and granitic rocks near the head of Aspen Creek. Along the south side of the Hidden Creek stock the strike changes again from northeast to northwest, and, within the marginal granitized zone, to west. North of the Hidden Creek stock similar changes in strike are found. These rapid variations in the strike of steeply dipping rocks throughout the Black Argillite Belt are in contrast with the uniformity of strike of steeply dipping rocks in the belts on either side. The contrast is mainly a function of the relative incompetence of rocks in the Black Argillite Belt.

STRUCTURE OF THE EASTERN BELT

The structure of the Eastern Belt, from Hidden Creek to the International Boundary, is dominated by the Sheep Creek anticline. The anticline continues south of the boundary and has been mapped north of Hidden Creek in the Ymir area (*see* McAllister, 1951, p. 35). It persists as a major anticline for at least 30 miles. The anticline was described first by Walker (1934) and recently in more detail by Mathews (1953). The writers studied the anticline south of Lost Mountain and its western flank between Lost Creek and Hidden Creek.

Between Lost Creek and Hidden Creek the structure consists of a major overturned isoclinal anticline referred to by Mathews (1953) as the eastern anticline and a subsidiary anticline on the west referred to as the western anticline. The anticlines have axial planes that strike north 10 to 20 degrees east and dip 60 to 80 degrees east. The axes plunge as steeply as 10 degrees south on the north side of Sheep Creek but reverse to as much as 10 degrees north on the south side of the creek. The youngest rocks repeated by these folds belong to the Laib formation. The distance between the base of the Laib on either limb of the eastern anticline is as much as 6,000 feet in the valley of Sheep Creek. The western anticline is much smaller than this and has the form of an overturned dragfold on the west limb of the eastern anticline.

South of the Lost Creek stock the Sheep Creek anticline is overturned but is more open than it is north of the stock. Between Lost Mountain and the South Salmo River the fold is clearly indicated by attitudes of beds and by repetition of members of the Quartzite Range, Reno, and Lower Laib formations. Rocks at this locality are higher in the section than those in the Sheep Creek camp. In deepest cross-sections the west limb of the anticline south of the Lost Creek stock dips steeply to the east and the east limb dips less than 45 degrees to the east. Dragfolds, and probably the axis of the major structure, plunge south 35 degrees west at about 10 degrees, but south of the Ripple Creek fault the plunge steepens to as much as 30 degrees. On the south side of the South Salmo River almost a complete cross-section of the upper part of the anticline is outlined by the quartzites and Reeves limestone; it is a broad arch uncomplicated by major dragfolds.

West of the Sheep Creek anticline, details of structure in phyllites of the Upper Laib formation are not well known. North of the Lost Creek stock structural evidence is derived from three isolated areas of outcrop—one between Billings Creek and the western slopes of Mount Waldie, a second on the steep slope north of Sheep Creek, and a third west of the Reno mine.

In the first area the major structure appears to be a complex, gently plunging isoclinal syncline. This interpretation is based on correlation of phyllite in the trough of the syncline with the Upper Laib formation, and of limestone along the east side of the Black Bluff fault with the Reeves limestone (*see* Fig. 3). No other correlation seems possible, but the form of the syncline has not been established. Foliation in general strikes north 20 degrees east and dips steeply east, but locally near the centre and western side of the syncline beds dip westward. Dragfolds and lineations plunge gently northward and most dragfolds are Z-shaped (*see* p. 50). The structure is almost certainly complicated by obscure bedding faults. One such fault is assumed to lie on the west side of the Reeves limestone near the Ore Hill mine because the limestone is abnormally thin and appears to pinch out to the north. Others probably exist but have not been recognized. Rock units cannot be traced northward down the lower part of the ridge east of Billings Creek because the slopes are heavily wooded and outcrops are scarce.

On the north side of Sheep Creek the Reeves limestone and the phyllite east of it appear to form a steep easterly dipping homoclinal sequence. To the east the phyllite is in contact with the Lower Reno formation on the western Sheep Creek anticline, and, because the Upper Reno is missing, the writers believe that a bedding fault separates the phyllite from the quartzite. The phyllite probably belongs to the Truman member, but the lithology is not distinctive enough to make certain this correlation. If the correlation is correct, the sequence west of the bedding fault is overturned and the fault truncates only part of the Reno quartzite. However, the phyllite may be part of the Upper Laib formation; if this is so the sequence west of the bedding fault faces east and might be on the western limb of the syncline described in the preceding paragraph.

West of the Reno mine the main structures between the western anticline and the Black Bluff fault are a small syncline and an anticline involving Truman, Reeves, and Upper Laib rocks. The syncline is overturned and isoclinal, with an axial plane striking north 15 degrees east and dipping steeply east. Dragfolds on the limbs plunge gently north. A narrow band of phyllite at the core of the syncline can be traced both north and south to points where it pinches out and the two bands of limestone join. From its position at the core of the syncline this phyllite is presumed to be part of the Upper Laib, although metamorphism makes it indistinguishable from the Truman phyllite. Phyllite on the east limb of the syncline is known to belong to the Truman member because it contains a distinctive section of limestone at the base. To the west the syncline is followed by a small anticline that exposes the Truman member and repeats the Reeves limestone, which is in contact with the Active formation along the Black Bluff fault.

In the vicinity of the Reno mine, Mathews (1953, p. 23) describes six members in the Laib group " of which the first, third, and fifth from the bottom are distinctly calcareous." In the present stratigraphic subdivision of the Laib formation the first limestone is the distinctive marker at the base of the Truman member. The third member of Mathews includes the Reeves limestone and also rocks of the Upper Laib that occur on the limbs and trough of the syncline just described. The fifth member is probably the Reeves limestone lying on the east side of the Black Bluff fault, and the sixth member is black argillite of the Active formation.

The rock units in this area have been traced north down the steep upper slopes of the Hidden Creek valley to a heavily covered area in a small basin south of Hidden Creek. Near the northern limit of outcrop, dragfolds plunge steeply northeast and the rocks swing from north to northwest in strike. This swing in strike involves rock units, isoclinal folds, and bedding faults, and is paralleled to the west by a swing in the strike of foliation in the Black Argillite Belt. Northwest of the small basin rocks typical of those in the Hidden Creek valley strike northwest, and to the west they swing in strike to almost due west. Most of the rocks in the Hidden Creek valley strike west and dip steeply. The structure is obscure, but in the Hidden Creek valley the Sheep Creek anticline and related structures appear to have been complexly folded on steeply plunging axes. Much careful study might unravel the over-all form and some of the details of the structural complexity.

Little (1950, p. 31) regards the rocks of the Hidden Creek valley as younger than those to the south (*see* p. 41) and, with Mathews (1953, p. 24), considers that the abrupt change in strike marks the trace of a major fault striking almost east. Local faults may exist along the line of the most pronounced change in strike, but no large offset is recognized. Northerly striking rocks of the Truman member and the upper part of the Reno quartzite north of the Reno mine have been traced into the northwesterly striking section with no evidence of offset. No faulting has been found farther to the west where the curve in strike is more gradual.

Between the South Salmo River and the International Boundary the Sheep Creek anticline plunges 20 to 30 degrees southwest. The Upper Laib and Nelway formations outline a gentle arch on the east limb of the anticline but are intensely folded on the west limb. East of Rosebud Lake, synclinal "tails" of lower Nelway limestone occur throughout the Upper Laib phyllites. These synclinal tails are overturned, with axial planes dipping southeast and axes plunging to the southwest. Along the southeast side of the valley containing Rosebud Lake the lower and part of the middle member of the Nelway formation dip steeply southeast and face northwest. This overturned sequence forms the hangingwall of the Black Bluff fault; to the northeast it is gradually transgressed by the fault, so that north of the South Salmo River only thin lenses of limestone, possibly basal Nelway, lie along the eastern side of the fault. In all this area, on the western limb of the Sheep Creek anticline, dragfolds and bedding cleavage relationships in the Upper Laib phyllites and lower Nelway limestones might be used to determine details of the structure. However, studies have not been detailed enough to determine whether or not a major subsidiary anticline, comparable to the western anticline of the Sheep Creek camp, exists south of the Lost Creek stock.

The western limb of the Sheep Creek anticline is outlined west of the Styx Creek fault by the top of the Reeves limestone, and south of the International Boundary by the base of the Nelway limestone (*see* Dings, 1956). Dips are gentle to the west and southwest, and the anticline is a broad arch. North and west of Nelway, dolomite and limestone of the Nelway formation dip gently to the west and south and do not show complex structures like those on the northwest side of the Sheep Creek anticline east of Rosebud Lake.

Determination of structure near Nelway is made difficult by the massive character of much of the dolomite and by the complex distribution of limestone and dolomite. Dolomitization of the lower limestone (*see* p. 29) is irregular, and limestone-dolomite contacts cannot be regarded as horizon markers and used to outline the structure. The attitudes of the limestone north and northwest of Nelway indicate that the axis of an open, southwesterly plunging syncline passes through Lomond Lake. To the northwest as far as the Black Bluff fault, the beds dip southward in what appears to be a homoclinal sequence. West of the Pend d'Oreille River the upper Nelway limestone lies on the overturned northwest limb of an anticline. Along the river the beds dip steeply southeast, farther south and higher on the slope they are vertical, and along the International Boundary they dip to the west and southwest. The gently dipping southeastern limb of the anticline has been mapped in the Metaline quadrangle (*see* Dings, 1956), but the anticline has not been recognized east of the transverse faults along the Pend d'Oreille River.

PATTERN AND SEQUENCE OF DEFORMATION

In this chapter, details of the form of individual folds and faults have been given. A structural sequence was outlined on page 47, and evidence for the sequence has been presented in subsequent descriptions. These details suggest a process of progressive deformation with implications extending beyond the map-area. One of the most fundamental structural features of the map-area is the curvature of the southern end of the Kootenay arc. More than one interpretation of the structural patterns is possible, but the simplest interpretation and that favoured by the writers is that the primary and secondary structures formed by the continued application of one set of regional stresses.

North of the South Salmo River, axial planes of primary folds dip eastward and the plunge of the axes is low. This pattern indicates a relative movement of east over west. In the Mine Belt secondary fold axes are parallel to primary fold axes, suggesting that the secondary folds developed by continued application of much the same stresses as those that produced the primary folds. The primary folds have bedding faults associated with them. The formation of attenuated isoclinal folds appears to have been accompanied by shearing of the limbs and, with continued movement, sheared limbs became bedding and thrust faults. These faults, which formed at a late stage in the period of primary folding, in general are not folded, but seem to have continued to be zones of movement during the secondary folding. A few of the faults are gently folded. Other faults, particularly gently dipping thrusts that transect both primary and secondary structures, may have originated during the secondary folding.

Southwest of the South Salmo River the pattern of folding differs somewhat from that to the north, but the structural history appears to have been much the same. The structural pattern is known best in the Mine Belt. Axial planes of primary folds dip to the south or southeast and axial plunges are low. Secondary, Z-shaped dragfolds plunge steeply to the southwest, indicating a relative movement of the south side westward. Bedding faults, initiated during the primary folding, are closely associated with many of these secondary folds, and movement on the faults during the secondary folding appears to have been mainly strike slip. The effect of secondary folding and of strike-slip movement on bedding faults has been to accentuate the curvature in the regional trend of the formations, a curvature that is deep seated and fundamental.

The evidence within the map-area for the age of the deformation is scant, but together with regional data it suggests that the major structures developed during the Late Mesozoic. Primary and secondary structures are cut by the Nelson intrusions which Little (1950, p. 30) has shown to be pre-Upper Cretaceous and post-Lower Jurassic. The Waneta fault truncates volcanic rocks of the Beaver Mountain formation regarded as Jurassic or Cretaceous (*see* Little, 1950, p. 29). Regional studies in the Kootenay arc suggest a mid-Palæozoic unconformity. The unconformity is obscured, however, by subsequent major deformation, which appears to have been that of the late Mesozoic orogeny.

CHAPTER IV.—LEAD-ZINC DEPOSITS OF THE MINE BELT

INTRODUCTION

The map-area is part of a larger mineralized region with important production and varied mineralization. Past production has been of gold, silver, lead, and zinc near Ymir and of gold and silver from the Sheep Creek camp. Present production is of lead, zinc, and tungsten from within the map-area. The present work has been restricted to the lime-bearing succession of rocks that contains important lead-zinc mineralization. This chapter is concerned with lead-zinc deposits; tungsten deposits are not included. All the producing mines and many of the prospects are in the Mine Belt, and so the following discussion is based on observations in and is strictly applicable to the Mine Belt. Some of the observations may have broader application, but lead-zinc deposits outside the belt are too few to permit sound generalizations to be made.

Most deposits in the Mine Belt have similar mineralogy, form, and occurrence. Only broad generalizations are included in this chapter. Details on which generalizations are based are given in the property descriptions of Chapter V.

Lead-zinc deposits of the Mine Belt include those of the Red Bird, Reeves MacDonald, Red Rock, Truman, Tungsten King, Jersey, Lucky Boy, H.B., Garnet, Aspen, Jack Pot, and Oxide properties. Most of these are old properties first described in the Annual Reports of the Minister of Mines between 1910 and 1920, and many were located prior to 1900. The deposits have been mostly of little economic interest until recent years because they are low in grade and contain mainly zinc. The old Emerald mine, now part of the Jersey mine, contained seams of high-grade galena that were mined continuously from 1906 to 1925. High-grade carbonate ore at the H.B. mine in oxidized parts of sulphide orebodies was mined as early as 1912, and a total of 17,200 tons was shipped between 1912 and 1927. Large tonnages of lead-zinc ore close to the old Emerald mine and beneath the oxidized parts of the H.B. orebodies were unknown before diamond drilling was done at the Jersey in 1946 and at the H.B. in 1948. Present production at the Jersey began in 1949. Sulphide orebodies at the H.B. were prepared for production in 1953, but production did not begin until 1955. Orebodies at the Reeves MacDonald mine were diamond drilled and partly developed for mining before 1930, but the first production was not until 1949. In 1956 the average monthly production of ore was 33,000 tons at the Reeves MacDonald, 31,000 tons at the Jersey, and 36,000 tons at the H.B.

Other lead-zinc deposits in the Mine Belt have been explored by surface and underground work. At the Jack Pot between 1949 and 1955 two significant zones of zinc mineralization were outlined. At the Aspen property old workings and more recent diamond drilling explored a zone of zinc mineralization. Diamond drilling and trenching on the Tungsten King and Truman groups of claims have disclosed scattered mineralization. A relatively small high-grade orebody was mined at the Red Rock in 1947, 1948, and 1949, but no recent exploration has been done to determine the extent of the mineralization. Extensive drilling on the Black Rock claims has not located significant mineralization, and drilling on the Rainbow group outlined a mass of sulphides containing mainly pyrite. Limonite zones at the Red Bird property and at the Oxide property have been explored underground and by diamond drilling, but no sulphide mineralization has been discovered. Secondary lead and zinc minerals occur within the limonite on these properties.

PRODUCTION AND GRADE

The total production of lead-zinc properties in the Mine Belt up to and including 1957 is given in Table IV. Periods of main production are given under the heading "Year."

The ores of the Mine Belt consist of sphalerite, galena, pyrite, and minor pyrrhotite in dolomite. The sulphides in general form lenses, irregular bands, or disseminated grains, and locally occur as massive bodies with only minor dolomite. The orebodies are mined by non-selective methods and the grade depends on the stope limits set. The average grade of ore milled in 1957 at all three producing mines was between 1 and 2 per cent lead and between 3.5 and 5 per cent zinc, a fraction of an ounce per ton in silver, and a few one-hundredths of 1 per cent cadmium. The grade and the lead-zinc ratio of individual orebodies and of parts of orebodies vary widely. Much of the ore is close to the average grade, but high-grade sections are found, particularly at the Jersey and H.B. mines. Parts of one of the H.B. orebodies averaged about 6 per cent lead and 11 per cent zinc, and parts of the Jersey A orebody averaged between 20 and 30 per cent combined lead and zinc. Too few data are available to permit generalizations regarding variations in the grade and the lead-zinc ratio.

Table IV.—Total Production of the Mine Belt to the End of 1957

Mine	Year	Ore	Gold	Silver	Lead	Zinc	Cadmium
		Tons	Oz.	Oz.	Lb.	Lb.	Lb.
Aspen	1918, 1920, 1934	32	1	1,169	951	804	....
H.B.	1912–1917 1955–1957	1,164,751	6	221,326	19,185,772	93,476,392	758,656
Hunter V	1902–1907 1927–1929	62,634	1,010	272,141	....	....	....
Jersey	1906–1925 1949–1957	2,844,121	....	241,532	115,388,267	237,532,215	1,656,812
Red Rock	1935–1936 1947–1949	508	5	4,781	180,748	169,440	....
Reeves MacDonald	1949–1957	1,930,410	....	144,347	36,791,018	140,035,269	830,633

Oxidized ores carrying secondary lead and zinc minerals have been mined at the H.B. and represent significant reserves at the Reeves MacDonald, Red Bird, and Oxide properties. Assays of as much as 25 per cent lead and zinc are reported from the old MacDonald adit. At the Red Bird, assays of as much as 5 per cent lead and 25 per cent zinc have been obtained; at the Oxide property, assays ranging from 1 per cent to about 6 per cent lead and from 2 per cent to about 25 per cent zinc are reported.

CHARACTERISTICS OF THE OREBODIES

Generalizations regarding the lead-zinc deposits of the Mine Belt are based mainly on characteristics of the orebodies at the Reeves MacDonald, Jersey, and H.B. mines. At these mines, four mineralized zones are known, although about fifteen orebodies have been named. More than a dozen other mineralized zones occur on the prospects. Little is known of the prospects, but, with the exception of the Red Rock, ore occurrences are all similar to those at the producing mines. In the following paragraphs, attention is drawn to details of form, mineralogy, association, and structure, mainly of orebodies at the producing mines. Generalizations based on these details are consistent with what is known of the undeveloped mineralized zones in the Mine Belt.

FORM AND STRUCTURAL CHARACTERISTICS

Lead-zinc deposits in the Mine Belt are replacements of sphalerite, galena, and pyrite in the Reeves limestone. They are elongate and irregular in outline and vary widely in attitude. At the Reeves MacDonald mine the mineralized zone,* which includes the Reeves, B.L., and O'Donnell orebodies, is at least 2,700 feet long parallel to the plunge.

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* The term "mineralized zone" is used in this chapter to denote a geological zone which may contain one or more orebodies.

It plunges steeply to the southwest. In cross-section it has the form of an attenuated syncline open to the west. The largest or "trough section" of ore is about 350 feet long in plan and at the widest part has been stoped to widths of about 80 feet. The northern and larger "limb section" of the synclinal orebody extends about 500 feet west from the "trough section" and ranges from a narrow, sparsely mineralized zone near the trough to a well-mineralized zone a few tens of feet thick farther west (*see* Fig. 18).

At the Jersey mine the orebodies occur in two principal zones with low dip and with long axes plunging gently to the south. One zone, which contains only the A orebody, is more than 4,000 feet long. It has a western section as much as 60 feet thick and 100 to 200 feet wide, and an eastern section 10 to 15 feet thick and of variable width. The other zone, which contains the B, C, D, and E orebodies, is tabular, more than 3,000 feet long, a few hundred feet wide, and a few tens of feet thick.

Orebodies at the H.B. mine constitute one mineralized zone plunging gently south. The largest orebody is at least 3,000 feet long. It is lenticular in cross-section, dips steeply east, and has a maximum height of about 450 feet and a maximum width of about 100 feet. Other orebodies are of the same general shape, and still others, known as cross-zones, are tabular and gently dipping.

Some mineralized zones are closely related to folds. The A orebody at the Jersey mine follows a fold known as the "A zone skarn roll," which is a gently plunging dragfold in skarn and argillite beneath the Reeves limestone. The C and D orebodies at the Jersey mine are on the flanks of a gently plunging open anticline. The Reeves orebody follows a steeply plunging isoclinal syncline open to the west. The orebody has the same plunge as the syncline and a similar form. It is significant that these three folds are all secondary (*see* p. 47).

Sulphides occur as lenses, irregular bands, or disseminated grains in dolomite (*see* Plate XV). Within the orebodies, lenses and bands of sulphides tend to be parallel to one another and somewhat parallel to banding in the surrounding rocks, but they have an irregular distribution. Bands of sulphides interfinger; they may be persistent, lens out gradually, or may be short and abruptly terminated. In general, sulphides lens out rapidly near the edges of mineralized zones. Some lenses have the form of folds, but bands of sulphides have not been folded. Instead, the sulphides appear to have selectively replaced parts of folds in the surrounding dolomite.

The sulphides are in textured dolomite. At the H.B. the dolomite is crackled and consists of light-grey massive dolomite cut by closely spaced irregular very fine carbonaceous films (*see* Plate XIV). At the Jersey the dolomite is banded, and at the Reeves MacDonald it has a flecked or streaky appearance known as "tweedy banding." Crackled and tweedy banded dolomite commonly have lineations parallel to fold axes.

These textures are the result of deformation. The crackled dolomite at the H.B. resembles a breccia. Banding at the Jersey is shear banding. Tweedy banding at the Reeves MacDonald may be a combination of both brecciation and shearing related to the syncline which contains the ore (*see* p. 144).

Locally, sulphides form the matrix of breccias (*see* Plate XVI). Sulphides in breccias are commonly massive and enclose rounded or angular fragments of dolomite. The breccias are rich in galena at the H.B. and Jersey mines, and contain mainly pyrite at the Reeves MacDonald. Many fragments are obviously rotated or deformed, and the breccias appear to be mineralized zones of fragmentation and movement. At the Jersey and H.B. it has been shown that some of the breccias occur along gently dipping thrust faults with small displacement.

PRINCIPAL SULPHIDES

Sphalerite is generally the most abundant sulphide, but in parts of the Jersey A orebody and in zones of breccia at the H.B., galena is more abundant. In much of the ore at the H.B. and in some at the Reeves MacDonald mine, pyrite is more abundant than sphalerite. The grain size of the sphalerite ranges from about 0.1 millimetre to 2 millimetres. Sphalerite generally occurs as rounded to irregular grains along the boundaries of dolomite crystals, but it is locally complexly intergrown with pyrite and galena. Where tremolite and diopside are present, sphalerite forms thin tabular grains between crystals and along cleavage planes of the silicates.

The sphalerite ranges in colour from honey yellow at the Reeves MacDonald mine to black at the Aspen and is medium to dark brown at most of the deposits. All the sphalerite contains small quantities of cadmium. The iron content of pale sphalerite at the Reeves MacDonald mine is less than 0.1 per cent and of black sphalerite at the Aspen is as high as 10 per cent. Brown sphalerite at the Jersey and H.B. mines ranges from about 2 to 10 per cent iron and averages about 6 per cent. Specimens from the Jersey mine show that the iron content of sphalerite may range from 3 to 10 per cent across about 2 inches of mineralized beds. A marked variation in colour within single grains of sphalerite at the Jersey can be seen in thin sections. Some grains of pale-brown sphalerite are rimmed by dark-brown to black sphalerite; others are a darker colour where they are in contact with pyrrhotite. Darkening of sphalerite has been noted particularly near certain lamprophyre dykes. The occurrences of darker sphalerite in the central and northern parts of the Mine Belt than in the southern part may be due to metamorphism of low iron sphalerite in the presence of iron sulphides.

Galena in general is present only in subordinate amounts, but locally it is the principal sulphide. It is commonly fine grained and closely associated with sphalerite. In parts of the Jersey A orebody (*see* p. 113) essentially massive fine- to medium-grained galena occurs in bands a foot to a few feet thick. In the H.B. cross-zones (*see* p. 102) fine-grained galena, alone or intimately associated with sphalerite, may be the main sulphide.

Pyrite is disseminated through all the ores of the Mine Belt but varies considerably in degree of concentration. In the Reeves orebody, in addition to disseminated pyrite, masses of fine-grained pyrite containing only minor sphalerite and galena are found. These occur at various places in the orebody but are most abundant at the west end and hangingwall side of the northern limb of the Reeves orebody (*see* Fig. 18). At the Jersey mine much of the banded zinc ore contains very little pyrite, but the A orebody grades into a large pyritic zone on the east and south.

Pyrrhotite occurs in minor amounts in all the deposits. At the Reeves MacDonald it is found only within and at the margins of certain lamprophyre dykes which cut the ore.

OXIDATION

Many of the lead-zinc deposits are deeply oxidized near the surface to an earthy yellow-brown gossan. The gossan contains limonite and secondary lead and zinc minerals including cerussite ($PbCO_3$), anglesite ($PbSO_4$), smithsonite ($ZnCO_3$), and hemimorphite ($H_2Zn_2SiO_5$). At the Oxide property, pyromorphite ($(PbCl)Pb_4(PO_4)_3$) and hemimorphite are the main lead and zinc minerals, and the zinc phosphate, parahopeite ($Zn_3P_2O_8.4H_2O$), has been found. At the H.B. the phosphates pyromorphite, hopeite, spencerite, and salmoite have been reported.

The principal oxidized zones in the map-area are on the Red Bird, Reeves MacDonald, H.B., and Oxide properties. Production of lead and zinc from oxidized zones has come mainly from the H.B., and minor production has come from the old Emerald. Oxidized ore mined at the H.B. from 1912 to 1917 and in 1924, 1927, 1949, and 1950 amounted to 28,987 tons, containing 3,977,535 lb. of lead, 9,858,432 lb. of zinc, 38,900 oz. of silver, and 6 oz. of gold. These figures indicate an average grade of about 7 per cent lead and 17 per cent zinc. Assays as high as 6 per cent lead and 25 per cent zinc have been obtained from oxidized material at the other properties.

The depth of oxidation of different orebodies varies greatly. At the Red Bird property, oxidation is reported to be complete throughout the main adit (*see* p. 137), at a depth of 250 feet below the surface, and in drill-holes 150 feet below the adit. At the Reeves MacDonald mine (*see* p. 144) the Point orebody on the Pend d'Oreille River and the Reeves orebody 1,000 feet above the river are only superficially oxidized, whereas the MacDonald zone, which is between the other two and less than 100 feet above the river, is extensively oxidized. At the Jersey mine the D orebody (*see* p. 114) is oxidized to a depth of several tens of feet, but the outcrop of the B orebody is only slightly oxidized. Oxidation at the H.B. mine extends to a depth of about 400 feet below the surface. The Lerwick zone at the Jack Pot property (*see* p. 126) is deeply oxidized, but the east and main zones are not. At the Oxide property, oxidation is complete to depths of 600 feet below the highest outcrop of the orebody (*see* p. 133).

Factors controlling the depth of oxidation are not well known and depend on local conditions, which differ from one deposit to the next. Most of the oxidation probably took place before the glacial period and depended on circulation of ground-water at that time. Glaciation has modified topography and may have removed much oxidized material. The distribution of oxidation can be understood only from a detailed knowledge of physiographic history.

DOLOMITE

Dolomite zones within the Reeves limestone contain the lead-zinc orebodies. The close association between ore and dolomite makes study of the dolomite essential to an understanding of the control of sulphide mineralization. A special study of dolomite zones at the Reeves MacDonald, Jersey, H.B., Aspen, and Jack Pot properties was made by L. H. Green (1954) in 1951. This work was done without a knowledge of the structure or of the general distribution of dolomite in the map-area, but it has been of particular value in the present work. The dolomite has not been restudied in detail, but all the known dolomite zones in the Reeves limestone in the Mine Belt have been mapped and their structural setting has been determined.

Dolomite is recognized in the field by its weathering characteristics, grain size, colour, and texture, as well as by simple chemical tests. Weathered surfaces of dolomite tend to be buff coloured compared with grey or white limestone, and when the two are associated the mineral dolomite stands in relief above the more soluble calcite. On fresh surfaces the most useful distinguishing characteristic of dolomite is its fine grain size compared with limestone (*see* Green (1954), p. 7). The reaction produced by a drop of dilute hydrochloric acid on the rock surface provides a quick test for dolomite, but a small percentage of calcite in a dolomite specimen may produce a misleading reaction. Green recommends immersing a specimen in dilute hydrochloric acid until differential reaction has produced sufficient relief to distinguish between the two minerals.

The term " dolomite " refers to the mineral $(CaMg)CO_3$ and in this report to the rock composed of more than 80 per cent of the mineral. The term " limestone " is used for a rock composed of more than 80 per cent calcite. In general, zones of dolomite contain little or no limestone. Most specimens of dolomite studied by Green contained well over 80 per cent dolomite and most specimens of limestone contained more than 80 per cent calcite. Specimens with moderate amounts of dolomite and calcite were generally composed of alternating bands of limestone and dolomite. Locally thin bands or lenses of limestone are associated with sulphides or serpentine in altered dolomite. Boundaries of dolomite zones are sharply defined and are mainly parallel to banding in the adjacent limestone. Extremities of the zones feather out by an intricate intertonguing of limestone and dolomite. Dolomite zones are usually within limestone and only at a few places do they extend to the argillites on either side of the limestone.

In the southern part of the Mine Belt, dolomite in the Reeves limestone is confined to the southern limb of the Salmo River anticline and to rocks between the anticline and the Argillite fault. On Iron Mountain and Truman Hill, dolomite is mainly on the right-side-up limb of the Jersey anticline near the base of the Reeves limestone. Near Sheep Creek, lenses of dolomite are found in many occurrences of the Reeves limestone.

Farther north dolomite is found on the Aspen property east of Aspen Creek. North of the Hidden Creek stock, dolomite is largely associated with sulphide zones on the Jack Pot property.

These occurrences of dolomite in the Reeves limestone in the Mine Belt have similar characteristics and are probably related in origin. Dolomite occurring in other formations and in other belts probably differs in origin from that in the Reeves limestone in the Mine Belt (*see* pp. 29, 36, and 38). It is significant that the only known occurrence of dolomite in the Reeves limestone outside the Mine Belt is close to quartz-sulphide veins in the southern part of the Sheep Creek camp. It is also significant that within the Mine Belt the dolomite zones are in a structurally complex area close to the Argillite fault.

The main features of typical dolomite zones are given in the following paragraphs.

Dolomite containing the Reeves orebody is more or less symmetrically located within a steeply plunging syncline, the Reeves syncline, in the Reeves limestone. The dolomite zone itself has a synclinal form and is similar in shape to and several times the size of the orebody (*see* Fig. 18). It is V-shaped in plan. Near the trough it is as much as 300 feet wide and along the limbs about 1,500 feet long. The orebody is in dolomite close to the limestone wedge between the two dolomite limbs. The dolomite has a streaky or "tweedy" banding (*see* p. 82) and commonly a poor lineation parallel to the plunge of the syncline.

At the Jersey mine two closely spaced zones of dolomite have been outlined. One is associated with the A orebody, the other with the B, C, D, E, and F orebodies (*see* p. 113 and Fig. 12). The zones have a low average dip and a gentle plunge to the south. They are more than 5,000 feet long, between 100 and 200 feet thick, and a few hundred feet wide. The orebodies are within the lower half of the dolomite and lens out laterally a few hundred feet from the edges of the dolomite zones. In shape the dolomite zones and the orebodies are dissimilar in detail. The dolomite is near the base of the Reeves limestone, locally in contact with rocks of the Truman member, and elsewhere as much as a few hundred feet above the Truman. Most of the dolomite is poorly banded.

One large lens of dolomite contains all the known orebodies at the H.B. mine. The lens plunges gently southward and dips steeply. It is not completely delimited but appears to enclose the orebodies and to be several times their size. The shape of the dolomite lens is similar in only the most general form to the orebodies. The dolomite is crackled or poorly banded and locally has a poor lineation plunging gently southward.

The dolomite zones at the mines just described are typical of textured dolomite found at most of the prospects in the Mine Belt. They contrast with massive dolomite in the Reeves limestone found west of the H.B. mine and south of the Reeves MacDonald.

Dolomite west of the H.B. mine occurs in relatively continuous bands, some of which have been traced for nearly a mile on the slope north of Sheep Creek (*see* Fig. 7). Dolomite in general is near the base of the Reeves limestone, but large lenses are also found near the top of the limestone. Locally limestone-dolomite contacts appear to be stratigraphic, but elsewhere they are not stratigraphic and dolomite intertongues irregularly with limestone. Most of the dolomite is light grey and is massive or very poorly banded. It contains scattered sulphides. Near the H.B. mine it is darker grey, vaguely banded, and contains the Garnet zone of sulphides (*see* p. 103).

Massive dolomite south of the Reeves MacDonald mine is known at the mine as the Prospect member and is the Reeves member repeated by a fold between the Salmo River anticline and the Argillite fault. The Prospect member forms a band outcropping intermittently for half a mile to the west and nearly 2 miles to the east of the Pend d'Oreille River. Massive dolomite is fairly continuous throughout the member, but locally lenses out into poorly banded limestone. Scattered sulphides are found at several places in the Prospect dolomite.

From a knowledge of the detailed relationships of the dolomite zones the following generalizations can be made:—

(1) The dolomite is not stratigraphic. On a regional scale the Reeves member is limestone. Within the map-area it contains no dolomite in the Eastern Belt except near veins in the Sheep Creek camp. In the Mine Belt complete sections on the overturned limb of the Salmo River anticline and on the Jersey anticline contain no dolomite for many miles along strike. On a local scale dolomite transgresses boundaries of the Reeves member. It is commonly in the lower part of the member but varies in position from the base to a few hundred feet above the base, within individual zones and from one zone to another.

(2) Structure controls the shape and distribution of dolomite zones. Regionally, dolomite zones are on the south and east sides of the Mine Belt within a few thousand feet of the Argillite fault. They are in a zone of intense deformation characterized by primary and secondary folds and bedding faults. Specific structures to which dolomite is related have been recognized at only a few places. The relation between dolomite and the Reeves syncline has been noted. Other dolomite zones on the south limb of the Salmo River anticline appear to be similarly controlled, but few details of their form are known. Dolomite zones at the H.B. and Jersey mines are not obviously related to one structure or one set of structures, but the general form of the zones and their plunge parallel to the fold axes are taken as proof that they are structurally controlled.

(3) Bodies of sulphides have the same plunge but only locally have the same form as the dolomite zones. In general they are not central to the dolomite zones. Most sulphides are within the dolomite, but at places they extend beyond the dolomite into limestone and, at the Jersey, into skarn. Sulphides are found locally in limestone of the Reeves member without associated dolomite (*see* p. 148). These relationships show that dolomite formed prior to the sulphides. It was undoubtedly a favourable host rock.

(4) Two types of dolomite are recognized. One is banded, mottled, or crackled and is referred to as textured dolomite; the other is massive or very poorly banded. In general the two types form separate masses, but textured dolomite is found at places in the massive type, and massive dolomite is present locally in zones of the textured type.

(5) Dolomite zones have been thermally metamorphosed and cut by granitic rocks of the Nelson intrusions. The metamorphism of dolomite is described by Green (1954, pp. 6 and 10). Silicates including diopside, tremolite, forsterite, and serpentine are found in dolomite at the Jersey, H.B., Aspen, and Jack Pot properties. Talc occurs at the H.B. closely associated with tremolite or in dolomite without tremolite. Serpentine rims grains of forsterite and is also found in dolomite without forsterite. These silicates have formed by thermal metamorphism associated with the Nelson intrusions. At the Reeves MacDonald mine, serpentine occurs adjacent to a large lamprophyre dyke.

Granitic dykes cut the dolomite zones at the Jersey mine. Relatively large irregular masses of granite as well as dykes cut the dolomite at the Aspen and Jack Pot properties.

The dolomite zones in the Reeves limestone are epigenetic replacements, but conclusive evidence of the age of the dolomitization in relation to the structural history has not been found. A secondary syncline has obviously controlled dolomitization near the Reeves orebody, and other lenses of dolomite on the southern limb of the Salmo River anticline are probably similarly controlled. At other localities it is not certain that dolomitization has been controlled by secondary structures.

Dolomitization took place before granitic intrusion. Contact relationships between granite and dolomite clearly show that granite intruded dolomite, and not limestone that was subsequently dolomitized. Dolomitization preceded thermal metamorphism related to granitic intrusion, as shown by the fact that the grain of the dolomite has been coarsened by the metamorphism and the silicates developed in the dolomite are characteristically magnesian.

CONTROL OF MINERALIZATION

Regional and detailed studies of the lead-zinc deposits have shown several important relationships. Among these are the structural setting, the relation of ore to dolomite, and the time relation between deformation and mineralization.

The regional setting of the orebodies is on the south and east side of the Mine Belt. They lie on the footwall side of the Argillite fault at distances ranging from a few hundred to a little more than 1,000 feet from the fault. No direct relationship between the fault and the orebodies is known, and where exposed the fault is not mineralized. The relationship is a regional one, and its ultimate meaning may be beyond the realm of field observation. Specific factors, such as the type and continuity of structures close to the fault or the areal distribution of limestone, were probably important, but their relative importance is not known.

On a smaller scale, mineralization has been controlled by secondary folds and by bedding or thrust faults. The Reeves orebody follows the Reeves syncline, a secondary fold on the south limb of the Salmo River anticline. This secondary fold is one of a series plunging steeply southwest. The Jersey orebodies follow secondary folds on the right-side-up limb of the Jersey anticline. The secondary folds are open, plunge gently south parallel to the plunge of the Jersey anticline, and mineralization is most intense in troughs and extends up the limbs of synclines.

Mineralized breccia zones follow bedding or thrust faults. The gently dipping breccia zones in the Jersey A orebody (*see* Plate XVI) and the H.B. cross-zones contain high-grade ore. A direct relation between the Jersey breccia ore in the A orebody and a thrust has been established (*see* p. 117), and a small offset is indicated on one of the H.B. cross-zones (*see* p. 103). Bedding faults are characteristic of the structure of the south and east sides of the Mine Belt. Their close association with banded as well as breccia ore at the Jersey mine has been established (*see* p. 119), and it is probable that they are of widespread importance in controlling mineralization.

It has been shown that dolomite zones with which the orebodies are associated are structurally controlled epigenetic replacements (*see* p. 86) and that dolomitization preceded sulphide mineralization. Structures that controlled dolomitization were probably closely related to those that controlled sulphide mineralization, but may or may not have been precisely the same structures. The Reeves orebody appears to be related to the same syncline as the associated dolomite zone, but at the Jersey and H.B. mines the structures followed by ore are not obviously those that controlled dolomitization.

Dolomite was the host rock favoured by mineralization, possibly because of its structural characteristics. Textured dolomite rather than massive dolomite has been extensively replaced because it was structurally more favourable for mineralization. Crackled textures resembling breccias, tweedy banding, and lineations interpreted as remnants of attenuated folds suggest that the mineralized dolomite has been extensively fractured and comminuted.

Structural and spacial relationships between the sulphide zones and the dolomite are taken as evidence that the sulphides replaced the dolomite. Textural relationships seen in hand specimens and thin sections, though not always conclusive, also indicate that the sulphides replaced and therefore are later than the dolomite.

Dolomitization preceded intrusion of the granite stocks and associated thermal metamorphism. The relative age of the sulphides and the stocks, however, is uncertain.

The variable iron content of the sphalerite may be interpreted to mean that the sphalerite has been thermally metamorphosed. Relationships between sulphides and metamorphic silicates provide contradictory evidence. In parts of the B and C orebodies at the Jersey mine, bands of silicates cut across bands of sulphides, and remnants of sulphides persist into the silicates in a manner suggesting that silication followed sulphide mineralization. At the H.B. and Jack Pot, on the other hand, sulphides lie between crystals and along cleavage planes of silicates and appear to have replaced the silicates. No satisfactory explanation of these contradictory age relationships has been found.

CHAPTER V.—DESCRIPTIONS OF PROPERTIES

The mining properties are described in alphabetical order, using the names by which they are most generally known. Reference is made to all the properties in the map-area, although many of them have been examined only briefly and tungsten mineralization has not been studied. The principal groups of Crown-granted claims and the owners are shown in Figure 3. Many of the mines and prospects are also shown in Figure 3.

Alps

In 1952 The Granby Consolidated Mining Smelting and Power Company Limited, head office, 1111 West Georgia Street, Vancouver, controlled a group of about sixty located claims between holdings of International Lead and Zinc Mines Ltd. (*see* Fig. 3) and Nelway and extending about 3 miles north from the International Boundary. During the first seven months of 1952, eight diamond-drill holes were drilled " blind " in the hope of discovering lead-zinc mineralization in limestone and dolomite of the lower and middle parts of the Nelway formation (*see* p. 28). A total of more than 5,500 feet was drilled. Locations of six of the holes (No. 2 to No. 7) are shown in Figure 3, and their logs are summarized in the Appendix (*see* p. 155). A few sections of core contained finely disseminated pyrite and are reported to have assayed very low in zinc. The core was carefully stored in a shed on the Nelson–Nelway highway about two-thirds of a mile north of Nelway. No further work has been done and most of the claims have been allowed to lapse.

Amco

The Amco group of twenty-seven Crown-granted claims and fractions owned by American Metal Climax, Inc., head office, 61 Broadway, New York 6, N.Y., formerly by The American Metal Company of Canada Limited, covers ground between Billings and Bennett Creeks south of Sheep Creek (*see* Fig. 3). Rocks on the claims are complexly folded and faulted members of the Laib and Active formations (*see* pp. 36 and 76). In the summers of 1952 and 1953 detailed geological mapping and prospecting on the Amco claims and adjoining ground were carried on, and in 1953 two diamond-drill holes, each about 1,500 feet deep, were drilled. One hole was at an elevation of about 4,000 feet on the old road to the Ore Hill mine, and the other was at an elevation of about 4,900 feet, 2,000 feet west of the road. No significant lead-zinc mineralization was found by this work.

[Reference: Moorhouse, 1952 and 1953.]

Aspen

The Aspen group of ten Grown-granted claims is near the head of Aspen Creek and covers a limestone area on either side of the creek. The claims are owned by Salmo-Malartic Mines, Limited, company office, 411, 67 Yonge Street, Toronto. A road 2½ miles long leads from the H.B. upper camp to the southern workings and old camp at the Aspen. In 1955 this road was washed out about a mile south of the Aspen camp. Roads and trails on the property and the main workings are shown on the geological map, Figure 6.

Two zones of replacement mineralization include: (1) A northern zone containing mainly sphalerite with local lenses of argentiferous tetrahedrite, and (2) a southern zone reported to have contained a pod of sphalerite and galena rich in silver. The northern mineralized zone has been traced in almost continuous outcrop for more than 1,000 feet along the hillside on the east side of Aspen Creek between elevations of 4,700 and 4,800 feet and is explored by four interconnected adit levels. The portals of Nos. 2, 3, and 4 adits were open in 1955, and the levels were accessible, but the manways between levels were in poor repair. The portal of No. 1 adit was caved. In old reports No. 2 adit is referred to as "A" adit and No. 4 as " B " adit. The southern mineralized zone is poorly exposed on surface in an area of scattered outcrops. It was explored under-

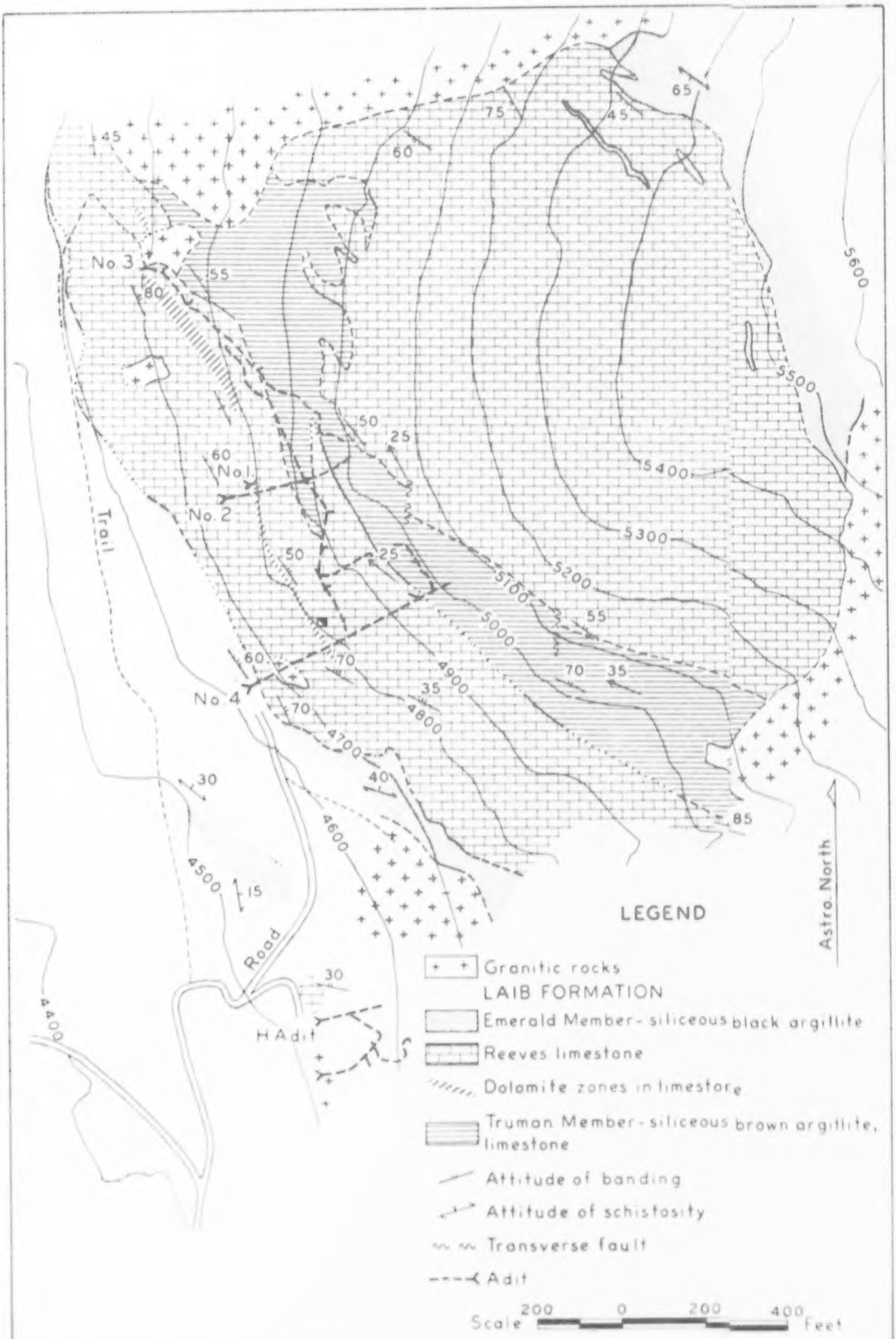
No. 3
No. 1
No. 2
No. 4
H Adit
Trail
Road
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
5500
5600
45
75
60
65
45
55
80
50
25
60
50
25
55
60
70
70
35
35
70
40
30
15
30
85
LEGEND
Granitic rocks
LAIB FORMATION
Emerald Member - siliceous black argillite
Reeves limestone
Dolomite zones in limestone
Truman Member - siliceous brown argillite, limestone
Attitude of banding
Attitude of schistosity
Transverse fault
Adit
Scale 200 0 200 400 Feet
Astro. North

Figure 6. Geological map of the Aspen property.

ground by an irregular working with two portals, both of which are now caved. This working is referred to as " H " adit by Walker (1929, 1934) and as the " G " tunnel workings in the Annual Reports for 1928 and 1929.

The first underground work on the property is reported to have been done in 1912 by P. F. Horton and H. M. Billings. In 1918 and 1920 Horton shipped silver ore from a zone near surface extending south from No. 1 adit. The 1918 shipment of 7 tons contained 434 ounces of silver, and the 1920 shipment, also of 7 tons, contained 140 ounces of silver. The southern mineralized zone was discovered in 1926, and a small shipment is reported to have been made from it (*see* Walker, 1934, p. 67). In 1927 the property was acquired from Horton and associates by Salmo-Malartic Mines, Limited, of Toronto, who have held the property to the present time. The property was actively explored by this company in 1927, 1928, and 1929, during which time more than 2,000 feet of underground work and 2,000 feet of diamond drilling were done. Underground workings were extended in 1933, and in 1934, 18 tons of ore containing 60 ounces of silver, 951 pounds of lead, and 804 pounds of zinc was shipped from the shaft northeast of No. 4 adit portal (*see* Fig. 6). In 1937, 1,700 feet of diamond drilling is reported to have been done. Sheep Creek Gold Mines Limited optioned the property from Salmo-Malartic Mines, Limited, in 1951 and drilled a total of 3,019 feet in eleven diamond-drill holes. Of these, two short holes were from underground in the " H " adit, five from underground in No. 4 adit, and four holes from surface north of No. 2 adit portal. The option was dropped, and no work has been done since 1951.

Sedimentary rocks on the Aspen property belong to the Laib formation. They are intruded by irregular masses of granitic rock and by lamprophyre dykes. The property is near the southern margin of the Hidden Creek stock, and the rocks are highly contorted and strongly metamorphosed. Rocks of the Laib formation include Reeves limestone, brown argillaceous rocks believed to belong to the Truman member, and black argillite correlated with the Emerald member. These rocks are well exposed on the steep burned-off slope east of Aspen Creek, on which the northern showings are located. The limestone is typically a grey and white banded rock that is locally very coarsely crystalline. The Truman argillite is mostly rusty-weathering brown to grey, and is locally greenish and siliceous. It is correlated with the Truman member because of its association with the Reeves limestone and its position in the rock sequence. Grey quartzitic rock within the argillite may represent metamorphosed parts of the Reno quartzite. The area shown as the Truman member in Figure 6 includes as many as four bands of argillite interlayered with grey and white limestone, regarded as isoclinal repetitions of Reeves limestone and Truman argillite. Black argillite underlies the Reeves limestone and is exposed along the base of outcrop west and south of the Aspen workings and on the ridge east of the main area of limestone. On the slope south of No. 4 adit the argillite is a hard grey to black siliceous rock and is altered to a green and white banded silicate rock near the granite. On the ridge the argillite is black near the limestone contact, but farther from the contact it is altered to a grey siliceous rock. Infolds of black argillite in the limestone near the contact indicate that it is probably a normal contact of Reeves limestone and Emerald argillite. The Argillite fault is probably within a few hundred feet east of this contact, but because the Emerald argillite is indistinguishable from rocks of the Active formation at this locality, the fault has not been located. Black argillite of the Active formation underlies large areas east of the Aspen property (*see* Fig. 3).

The major structure on the Aspen property is a fold with Truman argillite at the core and Reeves limestone and Emerald argillite on the limbs. The contact between the limestone and the Emerald argillite on the west limb dips consistently eastward, and is overturned. The same contact on the east limb dips westward and is also overturned. The structure has the form of a syncline with the oldest rocks at the core, and may be referred to as an overturned syncline. Complex minor folds occur throughout the limestone, which is abnormally thick. Most of them plunge northwest at angles between 5 and 35 degrees; some plunge gently southward and others eastward.

The structure is partly a combination of primary and secondary structures and is partly related to later deformation (*see* p. 47) near the Hidden Creek stock. Regional studies have shown that limestones on both sides of Aspen Creek are on the overturned limb of a major primary recumbent anticline and the overturned syncline is a secondary fold on the overturned limb. The pattern of folds farther south in the Mine Belt indicates that primary folds are isoclinal; such folds at the Aspen property have been largely obliterated by subsequent deformation and metamorphism. Small isoclinal folds are outlined by the contact between the limestone and the Truman member east of No. 2 and No. 3 adit portals. Isoclinal folds cause repetition and lensing of limestone and argillite in the area of Truman member shown in Figure 6. Lenses of black argillite in the limestone near the main contacts of the limestone west and east of the workings are isoclinal infolds.

The two mineralized zones on the property are replacement bodies in dolomitized Reeves limestone. The northern zone, south of the portal of No. 3 adit, contains banded and disseminated black sphalerite with pyrite and pyrrhotite in a gangue of grey and white dolomite with minor calcite. Galena is very sparse and silver values are low. In the same zone south of No. 1 adit, galena is locally abundant and is associated with argentiferous tetrahedrite in a gangue of siliceous dolomite. The southern mineralized zone explored by the "H" adit is reported to have contained high-grade galena and sphalerite and high silver.

The dolomite zone associated with the northern mineralization is as much as 100 feet wide near the portal of No. 3 adit and maintains a width of more than 50 feet for a distance of 700 feet south of the portal. Beyond this point it narrows abruptly, and no dolomite appears on surface for the next 150 feet to the south. Dolomite is again present south of No. 1 adit, but the zone is very narrow and may be discontinuous. Scattered sulphide mineralization has been discovered in pits and trenches along the length of this latter dolomite zone. The dolomite zone strikes northwest, parallel to the strike of the enclosing limestone, and between the surface and the underground workings it has an average dip of about 45 degrees to the northeast. No. 3 adit and the north drift of No. 2 adit follow the dolomite zone and show more continuous and higher-grade mineralization than is apparent on surface. No. 3 adit follows banded sulphides in dolomite to a point about 540 feet from the portal, beyond which it is in barren dolomite. On No. 2 level the best mineralization is from 180 feet north of the crosscut to the north end of the drift. The south drift of No. 2 level and all of No. 4 level are in limestone. Scattered occurrences of disseminated sulphides can be found in the workings, but they do not appear to form a well-defined zone. A raise from near the south end of the drift in No. 2 adit is reported to be joined with an old shaft on surface from which high-grade silver ore was shipped. An assay of selected specimens collected from a pile of broken rock at the collar of this shaft and assays of chip samples from No. 2 and No. 3 adits are given in the following table. Specimens from the collar of the shaft contain galena, tetrahedrite, pyrite, and pyrrhotite.

Adit	Location	Width	Silver	Lead	Zinc
		Feet	Oz. per Ton	Per Cent	Per Cent
No. 3	445 feet from portal	3.5	0.3	0.10	8.2
No. 3	220 feet from portal	5.0	0.3	Trace	8.5
No. 2	260 feet north of crosscut	3.5	0.4	Trace	5.9
No. 2	260 feet north of crosscut, 2.5 feet across strike from previous sample	1.0	0.3	Trace	4.6
....	Collar of shaft above No. 2 adit	Grab	26.3	0.69	0.09

The structural control of the mineralization is not apparent. The widest zone of sulphides is in the widest zone of dolomite, and high silver values appear to be confined to silicified zones. In general, mineralization and dolomitization appear to follow banding in the limestone. Complex dragfolds can be seen locally in the dolomite zone, but they bear no obvious relationship to the mineralization.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1915, p. 162; 1917, p. 170; 1927, p. 308; 1928, p. 348; 1934, p. E 22; 1937, p. E 53; 1951, p. 139; Green, 1954, p. 18; Walker, 1929, p. 266 A; 1934, p. 65.]

Bar

Between 1950 and 1957 a group of claims known as the Bar group was held by record by The Consolidated Mining and Smelting Company of Canada, Limited, company office, Trail. The claims were along the International Boundary between the head of Church Creek and the Red Bird property. Geochemical soil prospecting was done in 1950, and a geological map was made in 1951. Late in the year a vertical diamond-drill hole on Church Creek at an elevation of about 3,275 feet was drilled to investigate an area of anomaly. A summary of the log of the hole (D.H. No. 1) is given in the Appendix. No significant lead-zinc mineralization was found. The area covered by the claims contains mainly black argillite of the Active formation (*see* Fig. 3). The argillite is bounded on the north by the Argillite fault, north of which are rocks of the Reno and Laib formations. The fault dips to the south, and the hole went through the Active formation into the Reeves limestone and Reno quartzite beneath the fault.

Bell

The Bell group of claims, owned by L. A. Bell, of Fruitvale, is on Aspen Creek north of the H.B. and south of the Aspen property. In 1950 and 1951 Sheep Creek Gold Mines Limited optioned the claims and did 1,696 feet of diamond drilling. Eight holes were drilled; the longest was 420 feet. The holes were drilled near Aspen Creek about half a mile south of the Aspen camp. They were in contorted and altered rocks of the Active and Reno formations near the Argillite fault.

Bunker Hill

The Bunker Hill property, consisting of two Crown-granted claims, is owned by Waneta Gold Mines, of Nelson. It is east of Limpid Creek about 3 miles north of the Reeves MacDonald mine and is reached by following a logging-road which leaves the Nelway–Waneta road about three-quarters of a mile west of the Salmo River bridge (*see* Fig. 3). It is an old property from which there has been a small production of gold and silver from lenticular quartz veins containing pyrite and molybdenite. The veins are in grey and black argillites, phyllites, and argillaceous limestones of the upper part of the Laib formation, formerly regarded as part of the Reno formation. They are west of a small granitic stock, and the rocks are cut by dykes of felsite, aplite, and lamprophyre. The gold-quartz showings and workings are fully described in the Annual Report for 1936 (pp. E 18–E 21). In 1942 scheelite was discovered in two old pits near the granite stock east of the main workings (*see B.C. Dept. of Mines*, Bull. 10, Rev. 1943, p. 153). The occurrence is described as follows:—

> " Scheelite occurs as disseminated grains in a banded gneiss which appears to have been derived from argillaceous sediments. It is closely associated with fine-grained, lacy-textured pyrite that weathers to a yellow iron oxide. Distribution within the two pits appeared to be quite uniform, and two samples of representative material assayed 0.29 and 0.22 per cent tungstic oxide. The band of gneiss, not all of which is mineralized, dips eastward towards the granite and appears to be between 75 and 150 feet wide, and may be several hundred feet long between the granite and a band of skarn. The skarn contains only a negligible amount of scheelite."

There is no record that work has been done since 1943, and in 1955 the main workings were caved.

[References: *Minister of Mines, B.C.*, Ann. Rept., 1936, p. E 18; *B.C. Dept. of Mines*, Bull. 10, Rev. 1943, p. 153; Walker, 1934, p. 89.]

Caviar

Diem Mines Limited, of Wallace, Idaho, owns a group of nineteen Crown-granted claims along the International Boundary near Russian Creek (*see* Fig. 3). Zinc mineralization in the Nelway formation was found at two places on the Caviar No. 1 claim in 1949. One is on the west side of Russian Creek about 700 feet north of the International Boundary. A road has been made to the showing, and some bulldozer stripping and diamond drilling have been done. Honey-coloured sphalerite occurs as finely disseminated grains in grey and white banded limestone of the upper member of the Nelway formation. The grade is low and the extent of the mineralization is uncertain. The other occurrence is east of Russian Creek about 600 feet north of the International Boundary on the ridge northwest of Monument 186. A flat area a few hundred feet square has been stripped by bulldozer. Limestone and dolomite near the top of the middle member of the Nelway formation contain a few pockets of limonitic gossan, one of which is reported to have assayed more than 20 per cent zinc.

[Reference: Shenon and Full, 1951, p. 25.]

Ed

The Ed group of more than seventy located claims was held by International Lead and Zinc Mines Ltd., c/o 789 West Pender Street, Vancouver, between 1951 and 1954. The claims covered ground along the International Boundary between 4 and 6 miles east of Nelway. The main showings are on both sides of a westward and northward flowing tributary of the South Salmo River known locally as Lead Creek (*see* Fig. 3). During the summer of 1952 jeep-roads were built to the showings, geological mapping and prospecting were done, and some of the showings were stripped by bulldozer. In 1953 high-grade galena was mined south of Lead Creek by W. J. G. Grant, of Salmo, who shipped 1½ tons of ore, with a gross content of silver, 5 oz.; lead, 2,357 lb.; zinc, 44 lb.

Mineralization consists of galena and honey-coloured sphalerite in cherty dolomite of the upper part of the Nelway formation. In the showings north of Lead Creek, cherty and brecciated dolomite, containing disseminated sphalerite and galena, is exposed over an area 600 to 700 feet from east to west and about 500 feet from north to south. The sulphides occur in a number of relatively small, low-grade, irregularly spaced areas. Two main showings are south of Lead Creek. One, at an elevation of 3,950 feet about 700 feet north of the International Boundary, exposed in recent strippings and old trenches, is similar to the occurrences north of Lead Creek. At the other, at an elevation of 3,600 feet, 2,000 feet north of the boundary, a vein of medium-grained galena and light-coloured sphalerite is exposed in a shaft 10 feet deep. The vein strikes north 55 degrees west, dips steeply, and is exposed for a length of about 20 feet. It has a maximum width of about 2 feet, pinches out rapidly to the southeast, and continues to the west as a poorly defined zone of brecciated dolomite containing scattered clusters of disseminated sulphides. In 1953 lead ore was mined in the shaft and an adit was driven 80 feet at south 70 degrees west to a point about 60 feet vertically below the collar of the shaft. No sulphides were found in the adit.

The form of the mineralized zones has not been established, and there appears to be little continuity between them. The dolomite strikes uniformly north 30 degrees east and dips steeply to the east. The showings are part of a mineralized belt extending to the southwest in Washington.

Elm

The Elm group of nine claims is held by record by New Jersey Zinc Exploration Company (Canada) Ltd., company office, 525 Seymour Street, Vancouver. The claims cover ground between Active and Porcupine Creeks east of the Jack Pot and Oxide groups. Old workings on the property include two short adits near Porcupine Creek (*see* Fig. 3) and a few trenches. Recent work by the company has consisted of geological mapping, bulldozer stripping, and a small amount of diamond drilling. Mineralization consists of small lenses of sulphides in a steeply dipping limestone in the Active formation (9a of Fig. 3). The limestone is a few hundred feet wide, is bounded on each side by black argillite, and contains a number of dykes and irregular masses of granitic rocks. The sulphides include pyrite, pyrrhotite, and sphalerite and are locally associated with fluorite. Scheelite has been found locally.

Grouse

The Grouse group of fourteen claims is held by record by Diem Mines Limited, of Wallace, Idaho. The claims cover ground along the Salmo River between Creggan Creek and the logging-bridge about 1 mile north of the mouth of Creggan Creek. The claims are largely covered by deep unconsolidated deposits along the Salmo Valley and in terraces on both sides of the valley. The principal areas of outcrop are the Black Bluff and small bluffs west of the river and a short distance south of the logging-bridge (*see* Fig. 3).

At the Black Bluff several small pods of galena have been found in the Nelway formation near the Black Bluff fault (*see* p. 58), and narrow zones of limonitic gossan a few tens of feet long are exposed in Nelway dolomite near the south end of the bluff. The principal interest of the company, however, has been in the possibility of mineralization in the Reeves limestone northeast of Shenango Canyon beneath the unconsolidated material in the Salmo Valley. In 1951 a McPhar electromagnetic and a magnetometer survey were run of that part of the Salmo Valley covered by the Grouse claims. Results of the electromagnetic survey were inconclusive, but the magnetometer survey disclosed an anomaly near the logging-bridge at the north end of the claims. Subsequently a small programme of drilling was undertaken. By 1956 three holes had been collared, but only one had reached bedrock. It is about 3,500 feet south and about 1,800 feet west of the logging-bridge and encountered black argillite.

H.B. MINE AREA

The area includes the H.B. mine and Lucky Boy property of The Consolidated Mining and Smelting Company of Canada, Limited, and part of the Black Rock property of American Zinc Company. The detailed geology is shown in Figure 7. In the following paragraphs the geology of the area in general is described first, and the individual properties are then dealt with.

The H.B. mine area comprises two general areas of outcrop of the Reeves limestone and rocks stratigraphically close to it, one north and the other south of Sheep Creek. The southern area of outcrop, partly covered by the Lucky Boy claims, is on a steep heavily wooded slope south of Sheep Creek and on the crest of the ridge between Sheep Creek and Annie Rooney Creek, here referred to as the Lucky Boy ridge. Gravel terraces along Sheep Creek separate the two areas of outcrop, and the H.B. main camp and mill have been built on the terrace north of the creek. Roads from the main camp lead eastward to the H.B. upper camp. The H.B. upper camp is on the west side of Aspen Creek at an elevation of about 3,400 feet and about a quarter of a mile southeast of the 3500 level portal. It is east of the area shown in Figure 7.

The main workings of the H.B. mine are outlined in Figure 7. The 2800 adit level (portal elevation, 2,820 feet) is the main haulage and is connected by a vertical shaft to the 3500 adit level (portal elevation, 3,530 feet). The 3000 and 3200 levels, which are not extensive, and the old levels above the 3500 level, which are mainly inaccessible, are not shown in Figure 7. The portal of the 3100 level is at an elevation of 3,160 feet on the west bank of Aspen Creek east of the area shown in Figure 7.

STRATIGRAPHY

Rocks in the H.B. mine area belong to the Reno, Laib, and Active formations. The upper part of the Reno quartzite, the Truman member, the Reeves limestone, and the Emerald argillite form a stratigraphic sequence which is in fault contact with the Active argillite on the east. No simple stratigraphic sequence from the Reno quartzite to the

Emerald argillite is to be found, but the rock types are distinctive enough and parts of the sequence are complete enough to allow at most places no doubt about the correlation.

The Reno quartzite is exposed at a number of places on the north and south sides of Sheep Creek, and was encountered underground on the 2800, 3000, and 3100 levels of the H.B. mine. It is a grey to greyish-brown micaceous quartzite with grey, blocky, and locally calcareous quartzite at the top. In the micaceous quartzite, light-grey beds an inch to a few inches thick alternate with dark-grey micaceous beds. A moderately well-developed cleavage and many small dragfolds are common. Thin beds of greyish-white quartzite occur in the lower part of the Reno formation north of the 2800 portal. The upper part of the Reno formation is a grey blocky quartzite 15 to 25 feet thick containing lenses with visible quartz grains in a calcareous cement.

The Reno quartzite is overlain by the Truman member, consisting of brown phyllite and argillite with minor beds and lenses of limestone. Typically, a bed of white limestone a few feet thick with thin brown argillaceous streaks marks the base of the member, but this is not present everywhere. Most of the Truman member is brown phyllite or argillite, but locally it is green phyllite or schist. Blocky siliceous argillite and green and brown skarny argillite are common. In general, skarn and brown argillite occur on the south side of Sheep Creek and near the H.B. main camp; phyllite is found on the Black Rock claims north of Sheep Creek.

The Reeves limestone, and the dolomite zones associated with it, occur in three main bands north of Sheep Creek. The most easterly band contains the H.B. orebodies and is called the Mine limestone by company geologists (*see* Irvine, 1957). A large mass which contains the Garnet zone of sulphides near its western margin is called the Garnet limestone by company geologists. A third extensive band is on the west side of the Black Rock claims. Less continuous masses of limestone south of Sheep Creek have not been satisfactorily linked with the bands north of the creek.

The Reeves limestone, overlying the Truman member, is typically a fine- to medium-grained rock which weathers bluish-grey and on fresh surfaces has a grey or black and white banding. Commonly it contains minor amounts of fine-grained tremolite. A zone of coarsely crystalline diopside several feet thick and several hundred feet long occurs in the limestone north of the H.B. mill. The limestone contains dolomite of two general types—massive and textured. Massive dolomite is widely distributed north of Sheep Creek on the western edge of the H.B. claims and on the Black Rock claims, and is found at places on the Lucky Boy ridge. This dolomite is dull greyish-white, finely crystalline, and rarely shows banding. Textured dolomite (*see* Plate XIV) is found near the H.B. orebodies and locally in the Garnet zone. It is a finely crystalline light-grey or white rock with black flecks or bands. Close to the H.B. orebodies black or carbonaceous material occurs in minute streaks, giving the rock a crackled appearance. Both types of dolomite form large irregular lenses in the Reeves limestone. At a few places dolomite is at the base of the Reeves limestone and lies directly on the underlying argillite, but at most places a few feet of limestone separates the lowest dolomite from the underlying argillite.

Black argillite of the Emerald member outcrops along the western side of the most westerly band of the Reeves limestone on the Black Rock claims north of Sheep Creek. The argillite is crenulated, more or less well foliated, and contains whitish limy lenses a fraction of an inch thick and about an inch long. It is overlain to the west by a thick sequence of phyllite belonging to the Upper Laib formation, and is underlain on the east by the Reeves limestone. Two small masses of black argillite belonging to the Emerald member are found east of the Black Rock claims. One is in a shallow draw between the Mine limestone and the Garnet zone about 2,200 feet north of the 2800 level portal; the other is on the north slope and crest of the Lucky Boy ridge. At both these localities the argillite is grey to black, blocky, siliceous, and thinly banded. It is in fault contact with a variety of rock types on the west and overlies the Reeves limestone on the east. Rocks of the Emerald member are difficult to distinguish from the Active argillite in the H.B. mine area.

The Active argillite underlies wide areas east of the H.B. mine (*see* Fig. 3). The argillite is black, and near the mine and south of Sheep Creek close to the Reeves limestone it is mainly non-limy and more or less well cleaved. It is strongly crenulated on the Lucky Boy ridge, but is blocky farther to the north. On the north side of Sheep Creek detailed characteristics of the argillite are difficult to see in outcrops because weathering of disseminated pyrite and pyrrhotite has produced considerable rust. A distinctive band of limy argillite has been mapped on the north side of Sheep Creek about 1,000 feet east of the Mine limestone. Underground the Active argillite occurs in the 3100 level and the 3500 level; two black limy bands are present near the portal of the 3100 level, but elsewhere the black argillite is non-limy.

STRUCTURE

The structure of the H.B. mine area is an integral part of the regional structure of the central part of the Mine Belt described in Chapter III. The main events in the complex sequence of deformation, which have been recognized from regional studies, are outlined on page 47. Bedding and thrust faults and primary isoclinal folds are common in the H.B. mine area, but very few secondary folds have been recognized. Relatively large cross-folds on both sides of Sheep Creek warp the older structures and make the reconstruction difficult. North of Sheep Creek the isoclinal folds plunge gently south at about 20 degrees, and south of Sheep Creek at about 10 degrees. Axial planes of the folds dip steeply east. The fold displayed best is an isoclinal anticline on the south side of Sheep Creek on the bluffs forming the lowest outcrops on the western nose of the Lucky Boy ridge. Reno quartzite in the core of the anticline is flanked on either side by rocks of the Truman member. The quartzite at the crest of the anticline plunges beneath the nose of the ridge and is covered by a thin capping of limestone comprising the lowest bed in the Truman member (*see* Fig. 7, map and section C-C^1). The bed of limestone is pinched out on the western limb of the anticline, thickened on the crest, and continues intermittently down the eastern limb. The anticline plunges about 10 degrees south and the axial plane dips about 60 degrees east.

What is probably the same anticline is exposed north of Sheep Creek in a small area of outcrop on the Black Rock claims. The anticline cannot actually be seen, but the Reno quartzite forms the core and the Upper Reno and the Truman member are repeated symmetrically on the limbs. The anticline is followed on the west by an isoclinal syncline, on the west limb of which the same marker beds are again repeated. Foliation in all the rocks in these two folds dips steeply east.

Discontinuous tails (*see* p. 70) of brown micaceous argillite of the Truman member extending into the Reeves limestone are common in the H.B. mine area. They occur as a result of isoclinal folding, the argillite being in the core of isoclinal anticlines and the intervening bands of limestone in the troughs of isoclinal synclines. Two typical isoclinal anticlines are exposed north of Sheep Creek east of the anticline just described. The folds are highly attenuated, but in this locality the attenuation is exaggerated on the map (Fig 7) because the folds plunge southward nearly parallel to the slope of the hill. Drill-holes indicate that the argillite bands thicken gradually in depth and the limestone thins rapidly downward toward the troughs of the synclines.

Immediately east of these anticlines two other anticlinal tails of argillite occur in the lowest outcrops. The argillite is overlain by limestone and dolomite, and the anticlinal outlines are followed by the limestone-dolomite contact. This contact is not stratigraphic, but dolomitization has locally followed bedding. East of these two anticlines is a large lens of dolomite containing on its eastern side the Garnet ore zone. The dolomite tails out southward and to the north is split by a lens of limestone so as to form what appears to be a gently southward-plunging syncline.

The extent to which dolomite-limestone contacts may follow fold outlines farther to the north is uncertain. Gross relationships may suggest some broader structures, but details are obscured by vagaries of dolomitization.

Bedding faults are common in all the H.B. mine area and are displayed best on the south side of Sheep Creek. A typical fault and one that is readily recognized crosses the Lucky Boy ridge at an elevation of about 3,300 feet. It separates a narrow wedge of Emerald argillite on the east from the Truman member and the Reno quartzite on the west. The rocks dip steeply east; those east of the fault are overturned and those west of the fault are right-side-up. To the north the fault cuts through the Truman member into the Reno quartzite on its west side and through the Emerald argillite into the Reeves limestone on its east side. The fault strikes north and near the crest of the ridge dips steeply east; farther north and lower in elevation it flattens in dip and joins a gently east-dipping thrust fault.

The bedding fault just described is parallel to and about 400 feet west of the Argillite fault (*see* p. 56), which, south of Sheep Creek, separates Active argillite from the Reeves limestone. The Argillite fault is exposed between elevations of 3,000 and 3,100 feet. It strikes north, dips steeply east, and is parallel to foliation in both limestone and argillite. Farther south it transects foliation in the Active argillite. Below an elevation of about 2,850 feet the fault appears to flatten in dip. In a short adit near the point where the dip changes, the Argillite fault dips about 20 degrees east and cuts across contorted foliation in both limestone and argillite.

Another bedding fault dipping steeply eastward has been traced up the slope south of Sheep Creek from a point on the creek almost due south of the H.B. mill to an elevation of about 3,000 feet.

Thrust faults closely related to the bedding faults (*see* p. 55) are found on the south side of Sheep Creek. In general they parallel the formational strike but are flatter than the formational dip. One such fault, part of the Argillite fault, has just been referred to. Another has been traced northeast from near the crest of the Lucky Boy ridge at an elevation of about 3,100 feet. A third fault of the same type occurs south of Sheep Creek due south of the H.B. mill. The gentle easterly dip of the faults is indicated by their surface trace, by exposures of the fault planes, and by the fact that banding in limestone close to the faults dips gently even though the formational dip is steep. The faults transect isoclinal folds. Steeply dipping bedding faults branch upward from the thrust faults (*see* Fig. 7, section C-C[1]).

On the north side of Sheep Creek two bedding faults have been mapped in an area of limited outcrop on the Black Rock claims. The westernmost fault separates the Emerald argillite from limestone, dolomite, and brown argillite of the Reeves and Truman members. In the lowest outcrops the fault cuts acutely across isoclinal folds on its eastern side; to the north it has not been found. Diamond drilling shows that the fault dips less than 45 degrees east and in depth probably joins a second bedding fault to the east (*see* Fig. 7, section B-B[1]). The second bedding fault lies between the Reno quartzite and the Reeves limestone. Where exposed it is vertical and strikes north, but drilling indicates that in depth it dips eastward. In outcrops the fault is marked by a few feet of sheared rock which is parallel to the foliation on either side of the fault.

A complex bedding fault is exposed a few hundred feet north of the 2800 portal of the H.B. mine. It is cut off to the west by a northward-trending transverse fault, the Garnet fault, and curves southeast into the covered area near the mill. The bedding fault separates quartzite in the lower part of the Reno formation from complexly folded rocks of the Truman and Reeves members. Through much of its exposed length the fault strikes east and dips about 45 degrees north. To the east it rapidly swings in strike to south and in dip to east. The fault is exposed in the 2800 level about 350 feet from the portal. What is probably the same fault occurs on the 2800 level between 100 and 150 feet east of the main shaft. Near the portal it strikes north 75 degrees east and dips

70 degrees north, but near the shaft station it is a complex zone striking north and dipping about 50 degrees east.

Bedding faults in the H.B. mine area are subordinate to the regional Argillite fault, which follows the eastern side of the Mine Belt. Features of the Argillite fault seen underground in the H.B. mine are described on page 57. North of Sheep Creek the fault is not exposed on surface but can be located within a few feet at several places. The fault dips steeply eastward and has been folded and offset by later faults. Detailed mapping near the old H.B. No. 2 level portal about 600 feet west of the 3500 level portal shows that the fault zone is complex. A band of Reeves limestone as much as 60 feet thick, which is probably a fault slice, occurs in the Active argillite east of the H.B. dolomite zone. All the contacts between the black argillite and the limestone are regarded as faults. They are parallel to the formational banding and have been folded in a series of late cross-folds.

Zones of late cross-folds (*see* p. 47) add complexity to the structure of the H.B. mine area. The largest zone containing the most complex cross-folds is on the north slope of Sheep Creek near the 2800 adit portal. Similar cross-folds are found in the lowest outcrops on the south side of Sheep Creek southwest of the main camp. More open cross-folds occur near the north end of the H.B. orebodies.

Near the 2800 adit portal cross-folding of isoclinal folds has so complicated the structure that, even after very detailed mapping, contacts cannot be projected more than a few feet with assurance, and the over-all structure forms no recognizable pattern. The zone of cross-folds is crossed by a bedding fault about 200 feet north of the 2800 adit portal. South of the fault, rocks of the Truman member, which are rusty-brown argillite and skarny argillite, are isoclinally infolded with parts of the Reeves limestone. Cross-folds, which involve all foliation, have no consistent shape or plunge. In general, foliation west of the 2800 portal dips west and north of the portal dips north, but these attitudes are local. North of the bedding fault, 400 to 500 feet northwest of the 2800 level portal, well-defined cross-folds several feet across in the Reno quartzite plunge 30 to 40 degrees west. North of these folds the quartzite strikes north and dips steeply, and east of them it strikes east and dips 40 to 60 degrees north. The cross-folds are near the crest of a large cross-fold which in this locality plunges west. Another large cross-fold occurs in the limestone and argillite between 500 and 800 feet north and northeast of the portal. Small folds related to this latter cross-fold plunge 20 to 40 degrees northeast. The two large cross-folds appear to be parts of one complex cross-fold, the plunge of which changes abruptly. It is not certain whether the plunge, in changing from west to northeast, passes through the vertical or through the horizontal.

South of Sheep Creek, cross-folds plunging steeply northeast are exposed in the lowest outcrops southwest of the main camp. The folds are incompletely exposed but appear to be S-shaped (*see* p. 50) in plan. The relationship between this zone of cross-folds south of Sheep Creek and that north and northeast of the 2800 portal is obscured by the extensive cover along Sheep Creek and by the Garnet fault. The distribution of cross-folds and, to some extent, the shape of the folds suggest that they lie along one northeastward-trending zone.

Near the H.B. glory-hole southwest of the 3500 portal the regional strike changes from almost due north to north 20 degrees west, and near the northern limit of outcrop it swings again to north. This local change in strike is accompanied by dragfolds ranging from a few inches to several feet across and plunging steeply east down the dip of the formations. The Argillite and subsidiary bedding faults, as well as the H.B. orebodies, follow the change in strike. The change in strike is regarded as a gentle cross-fold of the same type as those close to Sheep Creek.

Foliation, bedding faults, and primary isoclinal folds are folded by the cross-folds. The cross-folds differ in shape, plunge, and occurrence from secondary folds in the central part of the Mine Belt (*see* p. 68). They are later than the secondary folds, though no secondary fold contorted by cross-folding has been recognized. The cross-folds are similar in many respects to cross-folds along the southern edge of the Hidden Creek stock (*see* p. 77), and it is suggested that the cross-folds at the H.B. and those near the Hidden Creek stock are related.

Only one important transverse fault has been recognized in the H.B. mine area, although several relatively small faults have been encountered underground. A major transverse fault striking north and dipping steeply west lies between the Mine limestone and the Garnet limestone. This is named the Garnet fault; it is exposed in trenches about 500 feet west of the 2800 portal and can be traced northward up the steeper part of the slope to the covered area where the slope becomes more gentle. The fault has been intersected in a number of drill-holes which indicate that the fault dips about 70 degrees west. It marks the contact between dolomite of the Garnet zone and Reno quartzite on the east, and the rocks close to the fault characteristically contain vein quartz and are silicified. The Garnet fault probably continues northwest of the H.B. glory-hole, but it is not exposed and has not been drilled in this area. It is thought to continue south but has not been found south of Sheep Creek. By projection it should lie east of the main zone of dolomite south of Sheep Creek along a narrow band of siliceous argillite separating the dolomite from the limestone to the east (*see* Fig. 7). However, it could not be recognized along this band of argillite, and the thrust fault to the south does not appear to be offset. The displacement on the Garnet fault is not known, but the distribution of structures and rock types on either side of the fault indicates that the western side is downthrown.

The over-all structure of the H.B. mine area is very complex, and can be determined only by piecing together the various structures of the types described. The Reeves limestone and Emerald argillite on the west side of the Black Rock claims are on the eastern edge of a sequence of phyllites which extends more than a mile to the west (*see* Fig. 2) and in general dips east and is overturned. East of this sequence a few hundred feet of beds are repeated many times by a series of relatively small isoclinal synclines and anticlines, all of about the same size. The overturned phyllites on the west have been traced north from the South Salmo River, where they occur in the overturned limb of the Jersey anticline (*see* p. 60). The isoclinal folds in the H.B. mine area resemble those lying between the overturned and right-side-up limbs of the Jersey anticline. The right-side-up limb of the Jersey anticline has not been recognized in the H.B. mine area and probably has been partly or completely cut out by the Argillite fault.

Repetitions of the Reeves limestone in the H.B. mine area expose bands of limestone and dolomite in a northerly striking belt that is more than 3,000 feet wide. The projection of these carbonate rocks northward is a natural concern in exploration. Three facts bear on this question.

(1) North of the H.B. mine the Reeves limestone outcrops on the east side of Aspen Creek, where it is in fault contact on the east with the Active formation and is stratigraphically overlain to the west by the Emerald argillite. Traced northward, the limestone thickens to a maximum of about 200 feet and is stratigraphically underlain on the east by the Truman member and this in turn by the Reno quartzite (*see* Fig. 3). West of Aspen Creek the outcrops of sedimentary rocks are all of phyllite of the Upper Laib. Thus, along the valley of Aspen Creek north of the H.B. mine, there is a relatively simple eastward-dipping overturned section from the Reno quartzite on the east into the Upper Laib phyllite on the west. This section is similar to that on the west side of the Black Rock claims north of Sheep Creek and is the northern extension of the overturned limb of the Jersey anticline.

(2) None of the isoclinal repetitions of the Reeves limestone on the H.B. property and on the east side of the Black Rock claims continues to the

north. Synclines of limestone and dolomite west of the Garnet fault rise above the surface at the north end of the H.B. mine area where the hill slopes gently to the north and east. These folds may be above a relatively gently east-dipping thrust fault which forms the eastern and upper contact of the Upper Laib phyllites. This possibility is suggested by the gentle dip of the western contact of the Reeves limestone found in drilling along the west side of the Black Rock claims (*see* Fig. 7, section B-B^{1}) and also by the fact that a horizontal hole drilled west from the 2800 shaft station in the H.B. mine reached Emerald argillite only 450 feet west of the shaft (Fig. 7, section A-A^{1}).

(3) On the east side of Aspen Creek north of the H.B. mine a northeastward-trending fault separates the Active formation from the rocks of the Reno and Laib formations. The fault is not considered to be the Argillite fault because it cuts sharply across the foliation. It probably continues southwest beneath the covered area north of the H.B. mine to a point just north of the most northerly outcrops of dolomite on the west side of the Black Rock claims. The fault has an apparent right-hand offset and probably has been downthrown on the south.

H.B. The H.B. group of eighteen Crown-granted claims and fractions is owned by The Consolidated Mining and Smelting Company of Canada, Limited, company office, Trail. Before 1946, mining and exploration at the H.B. was concerned mainly with oxidized ore discovered at an elevation of about 4,000 feet, west of Aspen Creek and almost a mile north of Sheep Creek. The original claims were located some fifty years ago by P. F. Horton, H. M. Billings, J. A. Benson, and S. N. Ross. The property and one of the claims was called the H.B. from the initials of Horton and Billings or Benson, but the mine soon became known as the Hudson Bay, and Spokane interests who held the property about 1920 were called the Hudson Bay Zinc Company. In 1911 the property was under lease and bond to the Consolidated Mining and Smelting company. First shipments of lead carbonate ore were made to the Trail smelter in 1912. The bond was relinquished, and in 1913 the property was leased to W. R. Salisbury, who continued to make shipments of lead ore.

The Salisbury lease expired in 1915, and a lease and bond was taken by Spokane interests. Work continued under the direction of R. K. Neil, and shipments of predominantly zinc-bearing ore were made to smelters in the United States. The zinc carbonate and silicate ore could not be treated at Trail and was shipped to plants which made zinc oxide, chiefly for use in the manufacture of paint. Shipments made in 1917 were in the name of W. G. Harris, of Silverton.

The original workings were the No. 2 level, started in 1911, and the Zincton crosscut 1,140 feet south of the No. 2 level portal driven by Horton and Billings in 1913. Late in 1915 a low crosscut, originally called No. 8 level, subsequently called No. 7 level, and now known as the 3100 level, was started. The crosscut reached a length of 1,900 feet and was completed in 1916. A total of 1,553 feet of diamond drilling from the crosscut failed to find any ore.

The property was idle between 1917 and 1925, when it was optioned to the Victoria Syndicate. The No. 4 level, now the 3500 level, was started in 1925, and exploration from it continued in 1926. The property was operated in 1927 by P. F. Horton, still one of the owners, and ore containing mainly lead was shipped. The property was bought in 1927 by the Consolidated Mining and Smelting company and lay idle for many years.

Starting about 1946 the company began geological investigations that led in 1948–49 to a considerable amount of surface diamond drilling. Large bodies of low-grade disseminated sulphides plunging gently south from the oxidized orebody were indicated by this drilling. Underground work was started in 1949 with the rehabilitation of the 3500 level, and a drive was made due south from the existing face for a distance of nearly 1,500 feet. A parallel drive was subsequently made about 230 feet to the west, 300 to 750 feet south of the old face of the 3500 level, and connected to the main drive by three crosscuts at 200-foot intervals. Diamond drilling from these two drives and from exploratory raises in 1950 partly delimited two orebodies—the No. 1 and the No. 2—and work until 1953 was aimed at developing these orebodies for production. In 1951 the 2800 level was driven from the Sheep Creek slope, and in 1952 it was extended and connected by a vertical raise to the 3500 level. Construction of the mill and main camp was started in 1951 and completed early in 1953. Both the mine and the mill were ready for operation by the end of March, 1953, but because of the relatively low prices for lead and zinc production was deferred. From 1949 to 1951, 16,828 tons of oxidized ore was shipped from old dumps and from underground to the Trail smelter.

The mine was rehabilitated in April, 1955, and the mill began operation in May of the same year. Since then the average milling rate has been about 35,000 tons per month. Production began with the mining of No. 1 orebody. Drilling and underground work have delimited the No. 1 and No. 2 orebodies and have led to the discovery of other orebodies, including gently dipping masses of sulphides known as cross-zones.

The H.B. orebodies are in the Reeves limestone immediately west of the Argillite fault. They plunge between 15 and 20 degrees south within a large lenticular mass of dolomite which also plunges gently south. The eastern or No. 1 and the western or No. 2 orebodies are poorly defined mineralized zones roughly elliptical in cross-section and remarkably persistent along the plunge. The No. 1 orebody extends from near the glory-hole* at least 2,000 feet south. In cross-section it is vertical or dips steeply east and has a maximum height of about 450 feet and a maximum width of 100 feet. The No. 2 orebody is not as extensively developed as No. 1, and is smaller and appears to be less persistent. It lenses out before reaching surface to the north up the plunge. It varies in cross-section but in general is nearly vertical, of the order of 150 or 200 feet high and 50 feet wide. To the north No. 2 and No. 1 orebodies are separated by about 100 feet of barren dolomite, but to the south near the shaft a mineralized zone, similar to the No. 2 but dipping 50 to 60 degrees east, has recently been found between them. The principal sulphides in these orebodies are pyrite and light-brown sphalerite occurring in narrow bands, irregular lenses, or disseminated crystals in dolomite. They are associated with minor galena and rare pyrrhotite. All the sulphides are as a rule fine grained.

In preparing the No. 1 orebody for stoping, vertical slots were driven across it so that several complete cross-sections were exposed; these were mapped by G. F. Warning, H.B. mine geologist. The sections (*see* Irvine, 1957, Fig. 2) show that a high proportion of the sulphides are in vertical or steep easterly dipping bands subparallel to the margins of the orebody. Some of the sulphides are in irregular lenses or bands dipping gently to the east or west. Masses of sulphides lens out relatively abruptly, not only at the margins of the orebody, but also well within it. Although the walls are not well defined, sulphides are fairly well restricted to the orebodies.

In addition to the relatively large lenticular orebodies, two† smaller tabular zones have recently been found. These are referred to as the X1 and X2 cross-zones. The X1 zone lies near the top and on the west side of No. 1 orebody. It dips gently east, plunges gently south, has a maximum thickness of about 15 feet, and a width of somewhat more than 100 feet. The limits of the X1 zone are uncertain, but it is known to extend for more than 300 feet along the plunge. The X2 zone, outlined by drilling, lies a few tens of feet below the bottom of No. 2 and No. 1 orebodies. It is somewhat thicker and wider than the X1 zone and dips south essentially parallel to the plunge of the other orebodies. The cross-zones contain fine-grained massive sulphides, commonly as a matrix in a coarse breccia. In general the grade of the cross-zones and the ratio of lead to zinc is higher than in the other orebodies. Development ore from No. 1 orebody averaged about 4 per cent combined lead and zinc and had a lead-zinc ratio of almost 1 to 5. Ore mined from the X1 zone has averaged between 10 and 15 per cent combined metals with a lead-zinc ratio of about 1 to 2.

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* Exploration in 1958 suggests that ore mined in the glory-hole is not part of the No. 1 orebody.

† By 1958 more than two small tabular orebodies had been found.

The north end of No. 1 orebody is completely oxidized to a depth of about 300 feet below the surface. Oxidation extends to the base of the orebody below its outcrop but does not continue far down the plunge of the orebody from the outcrop. Hemimorphite ($H_2Zn_2SiO_5$), smithsonite ($ZnCO_3$), and cerussite ($PbCO_3$) are the main ore minerals in the oxidized zone. The phosphates pyromorphite, hopeite, spencerite, and salmoite have also been found.

Dolomite surrounding the orebodies is a fine-grained black and white or light-grey rock (*see* Plate XIV). Black carbonaceous streaks follow fine irregular fractures, giving the rock a crackled appearance in hand specimens. Where carbonaceous material is abundant the dolomite resembles a breccia. On larger surfaces the black streaks give the rock a more or less well-developed banding, and commonly more than one direction of banding is seen. At places a poorly defined lineation plunges gently southward. Probably most of these structures in the dolomite have been developed by deformation.

The shape of the dolomite lens is not fully known, though in general it forms an envelope surrounding the orebodies. The top of the dolomite plunges southward parallel to the orebodies, but the form of the dolomite does not appear to reflect in detail the form of the orebodies. The dolomite in general passes into limestone, but on its western side little or no limestone separates dolomite from argillite of the Truman member. Banding in the limestone dips steeply and the upper limits of the dolomite probably cross it. The structure is uncertain, but limestone and dolomite appear to occupy a complex isoclinal syncline.

The syncline, known as the H.B. syncline, is indicated by relationships between the Reeves limestone and the underlying Truman member. East of the shaft, at the elevation of the 3500 level, the carbonate rocks are between 700 and 800 feet thick, and only a few thin bands of phyllite and argillite are found in them near the eastern and western contacts. On the 2800 and 3100 levels, directly below, brown argillite is interbanded with the limestone and dolomite, and few of the bands of carbonate rock are more than 100 feet thick. On surface, on the slopes northeast of the mill, a band of brown argillite tails out upward and is in what appears to be an isoclinal anticline of the Truman member in the Reeves limestone.

Little is known of the structures which controlled mineralization, and conclusions regarding them are speculative. The known orebodies are within the H.B. syncline but bear no obvious relation to it. The syncline is a primary fold which has been deformed by secondary folds and faults and subsequently by cross-folds. The cross-zones are controlled by gently dipping zones of breccia that are related to thrust faults and are considered to be secondary structures. Offset on the cross-zones was probably slight; the X2 zone may offset the dolomite-argillite contact west of it a few tens of feet. Control of the main orebodies is not obvious. Irvine (1957) relates the main orebodies to steeply east-dipping shear zones that formed during cross-folding. It is significant, however, that the orebodies plunge parallel to primary and secondary structures. Regional considerations suggest that the cross-folds are incidental to mineralization.

Garnet Zone

The Garnet zone of sulphide mineralization lies west of the Garnet fault and extends north from the switchback road to the 2800 portal for about 2,000 feet. The zone is on the Garnet and Legal Tender claims and the Black Rock No. 11 Fraction. (Old reports refer to the Black Jack group, which included the Legal Tender Crown-granted claim and three Black Jack recorded claims lying west of it.) The workings consist of about a dozen trenches which crosscut the zone and a few short adits. Much of the trenching was done late in 1926, and little surface or underground work has been done since. The Legal Tender and Garnet claims are part of the H.B. group, and ground originally covered by the Black Jack claims is now part of the Black Rock group of American Zinc Company. More than thirty diamond-drill holes to test the Garnet zone were drilled in 1948–49, and three holes were drilled at the southern end of the zone by American Zinc Company in 1951.

In the Garnet zone fine-grained sphalerite, pyrite, and very minor galena occur in scattered lenses and as disseminated grains in dolomite. The dolomite is light and locally dark grey, and is massive or poorly banded. Lenses of sulphides are parallel to the margins of the zone, which strikes north and dips steeply with the formational trend.

Drilling has delimited a more or less continuously mineralized zone 50 feet wide lying 150 to 200 feet west of the Garnet fault and outcropping between elevations of 3,500 and 3,800 feet. The indicated average grade is comparable to that of the H.B. No. 1 zone.

Lucky Boy

The Lucky Boy group, consisting of the Lucky Boy, Lucky Boy Fraction, and Mayflower Crown-granted claims, is mainly on the south side of Sheep Creek southwest of the H.B. main camp. The group was owned by F. H. McCaslin and August Schwinke in 1910. Descriptions in the Annual Report for 1915 indicate that most, if not all, of the workings were completed before 1915. In 1926 the property was optioned to R. J. White, of Wallace, Idaho, and early in 1927 the Lucky Boy claims were Crown-granted by Schwinke. Shortly afterward they were bought by the Consolidated company. In 1948 six holes were drilled in the zone of most extensive zinc mineralization.

Workings consist of more than a dozen old trenches and a few short adits and shafts. They expose scattered occurrences of sphalerite, pyrite, and gossan in dolomite, and of molybdenite in skarn.

An eastward-dipping dolomitized zone is exposed from the crest of the Lucky Boy ridge to the gravel terrace south of Sheep Creek about half a mile southwest of the H.B. main camp (*see* Fig. 7). The dolomite is grey and much of it is massive, but in places it is banded or crackled. Scattered lenses of sphalerite and pyrite lying parallel to the banding are found in several trenches. To test this mineralization, holes were drilled westward at 45 degrees by the Consolidated company at about 200-foot intervals along a line approximately parallel to the strike. The holes show that the dolomite continues to a depth of a few hundred feet, but only minor amounts of sphalerite were intersected.

Small lenses of massive dolomite also occur to the southeast on the crest of the Lucky Boy ridge near the southern limit of the outcrop. A few pits have been made in these rocks, and very small amounts of sphalerite have been found. To the east, near the top of the slope north of the Lucky Boy ridge, several lenses of dolomite contain scattered sulphides. Sphalerite is exposed in a few old pits in zones that appear to be no more than a few feet wide and to continue for more than a few tens of feet along the strike.

South of Sheep Creek, due south of the main camp between elevations of about 2,700 and 3,000 feet, several pits and short adits have been driven in lenses of skarn that appear to follow bedding faults. The skarn contains disseminated flakes of molybdenite. A few specimens were tested with an ultra-violet lamp, but no scheelite was found in them.

Black Rock

The Black Rock group of twenty-one Crown-granted claims and fractions is owned by American Zinc Company, c/o 927 Old National Bank Building, Spokane, Washington, and covers ground on both sides of Sheep Creek west of the H.B. group and northwest of Canadian Exploration holdings on Iron Mountain. Showings and drill sites on the claims north of Sheep Creek are reached by drill-roads from the H.B. main and upper camps. The claims south of Sheep Creek are traversed by the Emerald road.

Early history of the showings on the Black Rock group has not been recorded. In 1947 and for a few years thereafter the claims were owned by L. R. Clubine, of Salmo.

In 1951 they were optioned to D. I. Hayes, of Metaline Falls, Washington, for American Zinc Company, and subsequently this company purchased the group. In 1947 the Consolidated company drilled three holes near the Emerald road south of Sheep Creek. American Zinc Company, between 1951 and 1953, drilled thirty-four holes totalling between 17,000 and 18,000 feet on the Black Rock claims north of Sheep Creek and deepened two of those drilled by the Consolidated company south of Sheep Creek.

Geology of most of the Black Rock claims north of Sheep Creek is shown on Figure 7. Most of the showings are in the two westernmost bands of dolomite between elevations of 3,000 and 3,300 feet. The dolomite in this area is massive or very poorly banded. It contains irregular lenses of white quartz which strike north, dip steeply, and continue intermittently through most of the length of the dolomite zones. Some of the lenses are a few feet wide. They are not known to carry sulphides. Scattered lenses of disseminated sphalerite in dolomite, and at one place in limestone, have been found and explored by several trenches and four short adits. The largest lens, containing minor amounts of disseminated sphalerite, is approximately 15 feet wide and has been followed for about 30 feet along strike. It is exposed in the northernmost of two adits 150 feet east of the northwest end of the Black Rock drill-road. The area close to the adits was intensively drilled by American Zinc Company on five east-west sections 200 to 300 feet apart. The holes shown in section B–B[1] on Figure 7 and two holes south of this section failed to intersect dolomite; those to the north did not encounter significant amounts of sphalerite.

To the east several old pits about 1,200 feet northeast of the old cabin on the Black Rock drill-road contain small scattered lenses of sphalerite. Seven holes 600 to 700 feet long were drilled to test the southern part of the zone of dolomite associated with this mineralization, and two shorter holes were drilled in the covered area to the north. No significant zinc mineralization was encountered. A large stripping about 500 feet northeast of the old cabin was made in a search for the source of a sulphide-bearing boulder. No galena or sphalerite was found in place.

Showings on the Black Rock claims south of Sheep Creek are near the Emerald road between elevations of 3,400 and 3,700 feet. Old trenches and more recent bulldozer strippings expose small lenses of crackled dolomite in the Reeves limestone. The dolomite contains minor amounts of disseminated sphalerite and pyrite.

[References: *H.B.: Minister of Mines, B.C.*, Ann. Repts., 1915, p. 135; 1950, p. 124; 1955, p. 52; Canadian Mining Journal, Vol. 75, No. 5, pp. 202–205; Irvine, 1957, p. 124; Walker, 1934, p. 47. *Lucky Boy: Minister of Mines, B.C.*, Ann. Rept., 1915, p. 164; Walker, 1934, p. 54. *Black Jack: Minister of Mines, B.C.*, Ann. Rept., 1926, p. 278; Walker, 1934, p. 52. *Black Rock: Minister of Mines, B.C.*, Ann. Repts., 1947, p. 163; 1950, p. 128; 1951, p. 139; 1953, p. 117.]

Iron Cap

The Iron Cap group of eight Crown-granted claims and fractions is owned by Salmo Prince Mines Limited, head office, 108, 413 Granville Street, Vancouver. The claims are on the east side of Nugget Creek and extend from near Sheep Creek to more than a mile north of Sheep Creek. They cover dolomite and limestone in the Active formation on the eastern side of the Sheep Creek stock (*see* Fig. 3). The calcareous rocks contain local concentrations of sphalerite, galena, pyrrhotite, and pyrite. Workings on the property include two old shafts and a few bulldozer strippings and diamond-drill holes made in 1951 and 1952. One shaft is at an elevation of about 4,400 feet, 1,200 feet east and 1,900 feet south of the bridge over Nugget Creek on the first road running east from the Reno mine road. The shaft is reported to be 20 feet deep, and at the time of examination water lay about 12 feet below the collar. The shaft is in grey and white crystalline limestone with a vague banding dipping steeply to the east. The limestone contains lenses of quartz and clusters of lime silicates. Galena and sphalerite are exposed on the north wall of the shaft, and a sample across 6 feet of the highest-grade material assayed: Gold, 0.01 oz.

per ton; silver, 12.2 oz. per ton; lead, 17.9 per cent; zinc, 13.9 per cent. The sulphides cover the north wall, but do not appear elsewhere in the shaft or in outcrops adjacent to it. Some individual bands of sulphides are parallel to banding in the limestone, but the length of the mineralized zone appears to be nearly at right angles to the banding. About 200 feet north of the shaft, bulldozer strippings expose grey and white dolomite containing scattered lenses of limonitic gossan together with small amounts of sphalerite and galena. A chip sample of the highest-grade mineralization, taken across 5 feet perpendicular to banding in the dolomite, assayed: Gold, *nil;* silver, 0.2 oz. per ton; lead, 2.2 per cent; zinc, 2.0 per cent.

The second shaft, reported to be 30 feet deep, is 380 feet at south 15 degrees east from the first. The shaft follows a steeply dipping zone of sulphides in grey dolomite. The zone, which strikes north 30 degrees east, is a maximum of 3 feet thick and continues intermittently for about 150 feet north of the shaft. It does not appear to continue more than a few feet south of the shaft. The zone contains pyrrhotite and minor galena and sphalerite. A sample across 2 feet of the zone on the north side of the shaft assayed: Gold, *nil;* silver, trace; lead, 0.09 per cent; zinc, 1.5 per cent.

In 1951 and 1952 several holes were drilled near the first shaft and on the hill east of the shaft. No significant lead-zinc mineralization was found.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1924, p. 193; 1951, p. 138; 1952, p. 146; Walker, 1934, p. 69.]

IRON MOUNTAIN

Mines on Iron Mountain include the Jersey and the old Emerald lead-zinc mines, and the Emerald, Feeney, and Dodger tungsten mines, all owned by Canadian Exploration Limited; head office, 700 Burrard Building, Vancouver; mine office, Salmo. Figure 9 shows the geology of Iron Mountain and the principal underground workings and topographic features. The western slope of Iron Mountain rises steeply from a shallow valley at the head of Lime Creek (Plate IX), a small southward-flowing tributary of Lost Creek. The Main camp, including offices and a few residences, is near the north end on the east side of this valley, and the tungsten camp and mill is about half a mile to the south on the west side of the valley (Plate X). The Jersey townsite, consisting of about eighty residences, is on the relatively gentle south slope of Iron Mountain about a mile south of the Main camp.

The portals of the main haulage adits of the Jersey mine are on the southwest slope of Iron Mountain above the Jersey townsite. These are the 4000 and 4100 levels and the 4200 crosscut. The southern part of the Jersey mine, served by the 4000 and 4100 levels, is mined by conventional track methods (*see* Walkey and Little, 1954). The northern part of the Jersey and most of the Dodger are trackless, and workings in these mines, shown on Figure 9, rise somewhat irregularly to the east and north. The main workings of the Dodger mine are the 4200 crosscut, east of the tungsten mill, a drift to the north from it, and the Dodger 4400 drift driven from the north slope of Iron Mountain.

Workings of the old Emerald lead-zinc mine are on the western slope of Iron Mountain between elevations of 4,400 and 4,700 feet. The portal of the Feeney tungsten mine is immediately south of the Main camp, and the portals and open pits of the Emerald tungsten mine are on the lower western slopes of Iron Mountain between the Feeney and the tungsten mill.

Iron Mountain has been thoroughly burned over, and large trees remain only in scattered clumps on the north and west slopes north of the Emerald lead-zinc mine. The rocks in general are well exposed.

The name Iron Mountain, derived from the occurrence of rusty outcrops of mineralized zones, was in common use before 1895. The history of mining on Iron Mountain before about 1940 is mainly concerned with the Emerald lead-zinc mine. The first recorded shipment of lead ore was made in 1906. John Waldbesser was in charge of early work, and in 1909, when the Iron Mountain Limited company was formed, he became the manager. Ore was shipped regularly by Iron Mountain Limited until 1925. In 1919 a small concentrator was built on the lower slopes of the mountain below the mine; it was destroyed by fire in 1934. During the period of production of lead from the Emerald mine prospecting is reported to have been done for gold and some interest was taken in molybdenite in skarn.

The Jersey claim was Crown-granted by John Waldbesser in 1909, and a road was built from the Emerald to the Jersey showings in 1917. Between 1917 and 1919 several short adits were made and ore was shipped to the Emerald mill.

Between 1938 and 1942 and again between 1946 and 1952 exploration and development on Iron Mountain were under the direction of Harold Lakes, of Nelson. Extensive geological mapping and surface stripping were done between 1938 and 1941, and an adit was driven on lead-zinc showings on the Dodger claim. In 1942, following the recognition of scheelite in molybdenite-bearing skarn, Lakes discovered scheelite in quartz and in iron-bearing skarn in a series of long-forgotten workings driven in search of gold. This was west of the principal lead-zinc showings, along a granite contact. Later in the same year, scheelite ore of similar type was found near the Dodger lead-zinc zone.

Exploration of the tungsten-bearing zone was immediately successful, and on August 17th, 1942, the property was purchased from Iron Mountain Limited by the Dominion Government. Work thenceforth was accelerated by Wartime Metals Corporation, of Montreal, with E. E. Mason as manager of the Emerald Tungsten Project. The Emerald ore zone was developed, a tram-line constructed, and a 300-ton concentrating plant was built in the Salmo Valley west of the mine. The mill, completed in June, 1943, was put into production on August 1st, at a rate of about 200 tons per day, but on September 10th it was closed down.

Early in 1947 the property was bought by Canadian Exploration Limited. Rehabilitation proceeded rapidly, and milling commenced on June 12th; the tonnage treated was increased to approximately 260 tons a day by the end of that year. Exploration for additional tungsten ore was carried out at the same time, under the direction of Harold Lakes. This work was extended to a study of the Jersey showings, and by the end of 1948 an impressive tonnage of lead-zinc ore had been proved by diamond drilling.

The mining of tungsten ore was stopped at the end of 1948, and the last tungsten ore was milled on January 12th, 1949. The decision had been made to mine the lead-zinc ore rather than tungsten ore, and immediate steps were made to convert the mill. By March, 1949, the mill was handling over 300 tons per day. In the interval the road to the Jersey showings was improved, the power-line was extended, and compressors were moved from the Emerald workings. The surface was stripped and an open pit started in ore subsequently known as the B zone.

Tungsten concentrates accumulated before February, 1949, were shipped to London, England.

Production of lead and zinc from the Jersey has continued since 1949. Surface drilling in 1951 indicated that lead-zinc mineralization extended north from the Jersey showings for more than 6,000 feet and was continuous with orebodies in the Emerald lead-zinc mine. Operations were expanded to attain a production of 800 tons per day by the end of 1951 and 950 tons per day by the end of 1952. The mill capacity was 2,200 tons per day in 1954, and production has since been maintained at about half capacity.

Underground mining, using diesel-powered trackless equipment, began in 1952. Ore was transported from the mine to the mill by aerial tramway and by trucks over a road constructed in 1950 and 1951. Construction of a belt-conveyor system from the mine to the mill began in 1952 and was completed in 1953 (*see* McCutcheon *et al.*, 1954). The system consists of a series of underground and surface conveyors with connecting raises.

Early in 1951 renewed interest in tungsten led the Canadian Government to buy from Canadian Exploration Limited two blocks of ground, one including the known Emerald tungsten orebodies and the other the partly developed Dodger tungsten showing. A new mill was built by the company at Government expense on the west side of Lime Creek southwest of the 3800 portal. While the mill was being built, diamond drilling demonstrated extensions of the Dodger zone. The new mill and the Government blocks of ground were then bought back by the company and long-term United States Government contracts were obtained for the sale of concentrates. In 1952 the capacity of the mill was 650 tons per day, and ore was taken from the Emerald and Dodger mines and from the Feeney mine north of the Emerald. The rate of milling of tungsten ore gradually increased from 9,000 tons per month in 1953 to an average of 12,500 tons per month in 1955. Most of the ore came from the Emerald mine. In 1956 the average milling rate increased to 17,300 tons per month and much of the ore was from the Dodger mine.

STRATIGRAPHY

Rocks exposed on Iron Mountain include parts of the Quartzite Range, Reno, Laib, and Active formations. Because of structural complexities, a complete and simple stratigraphic section is not exposed on Iron Mountain itself. The section exposed on the northwest slope of Truman Hill 3 miles south of Iron Mountain (*see* Table III) is regarded as the type section. On Iron Mountain the Reeves limestone and underlying rocks are exposed at places on the right-side-up limb of the Jersey anticline (*see* p. 68). A section from the top of the Reno formation into the upper part of the Laib formation is exposed on the overturned limb of the anticline west of Iron Mountain. Parts of the Reno formation and Truman and Reeves members are repeated several times in the central zone of isoclinal folds between the limbs. The Active formation occurs east of the Iron Mountain fault. Details of the stratigraphic section as found at various places on Iron Mountain are given in the following paragraphs.

Rocks thought to be part of the Lower Navada member of the Quartzite Range formation outcrop east of the Quartzite Ridge in an area extending from below the limestone bluffs east of the Jersey 4200 portal south to the gravel terrace north of Lost Creek. The rocks are on the Truman anticline and are truncated on the east by the Iron Mountain fault. The Upper Navada white quartzite, which forms the Quartzite Ridge, is underlain to the east by brown micaceous quartzite that appears to be between 100 and 200 feet thick, and resembles the upper part of the Lower Navada member. The brown micaceous quartzite is underlain to the east by interbedded impure white and brown micaceous quartzite similar to the lower part of the Lower Navada member exposed on Truman Hill. The Upper Nugget member (*see* p. 20) is not exposed, and the Lower Navada east of the Quartzite Ridge is many times thicker than that exposed on the north slope of Truman Hill.

The Upper Navada white quartzite forms the main part of the Quartzite Ridge. The quartzite is blocky. On the east and west sides of the ridge, well-marked joints strike northward and dip steeply eastward. In the centre of the ridge, joints form gently undulating fold-like surfaces plunging 25 to 30 degrees southward parallel to the regional structural plunge. Many of these joints are probably parallel to bedding in the quartzite, though no bedding can be seen, but it is doubtful whether the joints show the entire structure.

The lower part of the Reno formation outcrops west of the Quartzite Ridge overlying the Upper Navada white quartzite. Only the Lower Reno, a rusty-brown micaceous quartzite, is exposed in this locality, and elsewhere on Iron Mountain only the upper part of the Reno formation is found. The Upper Reno quartzite outcrops in two subparallel bands running southward from the Emerald stock through the Jersey townsite, and as a poorly exposed band 100 to 200 feet east of the Main camp. The rocks in these bands are brown micaceous and grey blocky quartzite. The brown micaceous quartzite commonly displays a blotchy weathered surface. The grey blocky quartzite contains lenses of calcareous quartzite a few inches thick and a few feet long with opalescent quartz grains as much as one-eighth of an inch across in a calcareous or lime silicate cement. In addition to these surface exposures the upper part of the Reno quartzite is exposed underground, in the Dodger 4200 crosscut and in the Jersey 4000 and 4100 levels.

The Truman member of the Laib formation, overlying the Reno quartzite, has been highly metamorphosed on Iron Mountain. Calcareous sections have been converted to rocks rich in brown garnet; more argillaceous sections are green and brown mottled or banded hornfels containing garnet and pyroxene, and quartz. These rocks are referred to locally as skarn and skarny argillite. The Truman member also contains spotted quartz-biotite hornfels and phyllite known locally as brown argillite.

The Truman member is exposed in a zone of very complex structure on the steep western slope of Iron Mountain and the west side of the Quartzite Ridge. In this zone fairly continuous bands of brown argillite, skarn, skarny argillite, and skarny limestone a few feet to a few tens of feet thick can be traced along strike for hundreds of feet. Rocks in this zone have been squeezed into attenuated isoclinal folds and cut by bedding faults, so that complete sequences of the Truman member can be recognized at only a few places. The most complete section of the Truman member is on the west side of the Quartzite Ridge about 2,000 feet south of the Jersey townsite. The sequence is right-side-up and dips 30 to 50 degrees east, and is essentially the same as that on Truman Hill. The maximum thickness is about 120 feet. Another apparently complete section of the Truman member is exposed in road cuts 500 to 800 feet along strike south of the portal of the Dodger 4200 crosscut. This section dips eastward and is overturned. The Truman member is exposed at many places underground and is encountered in diamond drilling. In the Jersey mine the Truman member dips at low angles and appears to be gently folded, but detailed study reveals that the rocks are highly deformed and complexly folded. The base of the member as exposed in the Jersey 4000 and 4100 levels and in the Dodger 4200 crosscut is well defined, and the structure of the underlying quartzite is relatively simple. The top of the member is obscured by complex isoclinal infolding of rocks of the Truman member in the Reeves limestone. The interval between the top of the Reno quartzite and the limestone and dolomite of the Reeves member contains a complex assemblage of brown argillite, calcareous argillite, skarny argillite, and grey and white argillaceous limestone. These rocks belong mainly to the Truman member, but they also include infolds of the lower part of the Reeves limestone.

Most of the limestone on Iron Mountain belongs to the Reeves member. Limestone covers the top of the mountain in a gently eastward-dipping mass 600 to 800 feet thick. On the western slopes of Iron Mounain and west of the Quartzite Ridge, discontinuous narrow bands of limestone appear to be isoclinal synclines of the Reeves limestone. Along the lower western slopes of the mountain close to the Emerald mine the Reeves limestone occurs as a steeply eastward-dipping band 300 to 400 feet thick which continues southward to the bluffs along the east side of Salmo Valley and along the South Salmo River.

The limestone is crystalline, with a grain size generally between one-sixteenth and one-eighth of an inch, and locally as much as one-half an inch. It weathers blue-grey and on fresh surfaces has a pronounced black and white banding. The limestone commonly contains fine or coarse crystals of tremolite and diopside and rarely contains subhedral crystals of brown garnet.

Lenses of dolomite occur within the Reeves limestone close to the lead-zinc orebodies. The dolomite is light or dark grey, generally finer grained and less well banded than the limestone. It crumbles and weathers to a yellowish-buff colour on the surface, but underground it can be distinguished from limestone only by the use of dilute acid.

In the Jersey mine area (*see* Fig. 9) dolomite occurs in what appears to be the lower part of the Reeves limestone but is confined to the right-side-up limb of the Jersey anticline. It is irregular in thickness and distribution, and although it is near the base of the Reeves limestone, it is not confined to one stratigraphic horizon. Dolomite lenses associated with the main orebodies are commonly as much as 100 feet thick and underlie much of the limestone on the top and upper slopes of Iron Mountain. Small lenses of dolomite are found above the main dolomite zone, but they rarely are more than 200 feet above skarn and argillite of the Truman member. In places dolomite is in contact with the underlying skarn and argillite, but most commonly it is separated from them by a few feet of limestone.

The Emerald member of the Laib formation overlies the Reeves limestone and in the Jersey mine area is found only on the overturned limb of the Jersey anticline. In outcrops and road cuts west of the Jersey townsite the argillite is a black, slightly limy, poorly banded rusty-weathering rock indistinguishable from parts of the Active argillite, which covers wide areas east of Iron Mountain. Farther north near the Emerald mine, Emerald argillite on weathered surfaces has a grey mottled appearance or is a uniform dull grey and is not limy. Metamorphic silicates, mainly diopside and tremolite and locally zoisite, can be seen in these rocks under the microscope; the change in colour is a result of thermal metamorphism near the Emerald stock.

West of the Main camp the Emerald argillite is overlain by grey, brown, and green phyllite and micaceous quartzite belonging to the upper part of the Laib formation. Details of the stratigraphic sequence in these rocks are not known. In close mapping, only a few distinctive rock units have been traced.

Rocks of the Quartzite Range, Reno, and Laib formations are in fault contact on the east with those of the Active formation. The Active formation (*see* p. 33) is dominantly black argillite but also contains a variety of argillaceous limestones and limy argillites. Along the eastern side of the Jersey mine area the Active formation is mainly poorly cleaved and thinly banded black argillite. Disseminated pyrite and pyrrhotite make many outcrops rusty. Near the south end of the Emerald stock the argillite is blocky and siliceous. Grey and black limestone and calcareous argillite containing fibrous masses of coarse tremolite occur about a quarter of a mile east of the eastern end of the Jersey townsite. Most exposures show a poor cleavage or a poor banding; minor contortions commonly obscure the over-all attitude of the rocks. The structure and stratigraphic sequence of the Active formation in the Jersey mine area are not known.

The sedimentary and metamorphic rocks are cut by granite, the main masses of which in the Jersey mine area are the Emerald and Dodger stocks (*see* Fig. 9). Although the granitic rocks have not been studied in detail, the following observations outline their main features. The Emerald stock outcrops near the Main camp and east of the Emerald mine. Underground work has shown that granite continues southward beneath a shallow capping of metamorphic rocks and joins the granite that outcrops near the Jersey townsite. The whole mass is referred to as the Emerald stock. The Dodger stock outcrops near the Dodger 4400 mine portal and has been followed southward in the Dodger mine to the 4200 crosscut. Although it probably joins the Emerald stock in depth, this has not been proved, and the masses are considered separately.

Rocks exposed on the surface are fine-grained light-coloured granite. Mineralogical analyses of thin sections of five specimens selected at random from both the Dodger and the Emerald stocks gave an average of 39.1 per cent quartz, 36.2 per cent potash feldspar, 22.5 per cent plagioclase, 1.2 per cent muscovite, 0.7 per cent biotite, and 0.3 per cent accessories, and the essential constituents in none of the analyses differed more than 2 per cent from the average. The potash feldspar is microperthite, the plagioclase is unzoned oligoclase, and the main accessories are apatite, sphene, garnet, and magnetite. Medium-grained, less siliceous facies occur more deeply within the stocks, and a variety of contact facies are exposed in underground workings. A mass of pegmatite made up of coarse-grained quartz and feldspar occurs at the south end of the outcrop of the Dodger stock.

The granitic stocks have the general form of northerly trending ridges. Diamond drilling along the western side of the Dodger stock to depths of 800 feet indicates that on the average it dips steeply westward. In the Emerald glory-hole the western side of the Emerald stock is vertical or dips steeply east, but underground work and diamond drilling to depths of 1,500 feet below the Jersey townsite indicate that on the average the contact dips steeply westward. The top and eastern sides of the stocks, as well as the shape of the western sides, are very irregular in detail. Dykes and protrusions of granitic rock and major swings and bulges of the contacts are common. The stocks cut across the wallrocks in both strike and dip. Rock types and pregranitic structures can be projected across the stocks without offset, and locally inclusions of wallrock maintain their position and orientation well into the granitic mass. These facts indicate that the stocks were passively emplaced. The cross-cutting form of the stocks and dyke-like apophyses suggest the granite is of magmatic origin. None of the surrounding wallrocks have been granitized.

STRUCTURE

The structure of the central part of the Mine Belt, dominated by the Jersey anticline, has been described (*see* p. 68). In the Jersey mine area the anticline is overturned with axial plane dipping eastward; the recumbent part of the anticline lies to the west. The Jersey lead-zinc orebodies are near the base of the Reeves limestone on the right-side-up limb of the anticline. The Emerald tungsten orebodies are along the contact between the Emerald argillite and the Reeves limestone on the overturned limb of the anticline. The intervening zone of complex isoclinal folds underlies most of the western slope of Iron Mountain and extends south along the western side of the Quartzite Ridge.

The most complete section of the overturned limb and the complex folds east of it are exposed for about half a mile south of the outcrops of the northern part of the Emerald stock (*see* Fig. 10, sections C-C^1 and A-A^1). The Reeves limestone, with the Emerald black argillite on the west and brown argillite and skarn of the Truman member on the east, dips 45 to 55 degrees eastward. Immediately east of the Dodger 4200 portal the upper part of the Reno quartzite is exposed in the core of an isoclinal anticline on either side of which is repeated the basal limestone of the Truman member. Dragfolds in the quartzite plunge 15 to 20 degrees south, somewhat steeper than the slope of the hill, and about 1,500 feet south of the Jersey townsite the quartzite on the crest of the anticline plunges beneath rocks of the Truman member. Attenuated dragfolds can be found in outcrops of quartzite, but the anticline cannot be seen. To the east, this anticline with Reno quartzite at the core is followed by a complex syncline containing rocks of the Truman and Reeves members. The syncline is recognized from the fact that a second anticline of Reno quartzite appears on its eastern limb, but the syncline is not a simple structure. Foliation dips steeply eastward, and attenuated dragfolds, well exposed in road cuts a few hundred feet southwest of the Jersey 4200 portal, plunge gently south. The syncline cannot actually be seen, but it is judged from the pattern of the dragfolds that the synclinal axis is about 75 feet east of the western anticline of Reno quartzite. Lenses of skarn and limestone within the syncline can be traced for only short distances, and their structural significance is uncertain. The Reno quartzite on the eastern side of the syncline forms another isoclinal anticline similar to that on the west. Rocks of the Truman member are repeated on the eastern side of this second anticline, and they and the quartzite are cut off on the east and south by a bedding fault.

Southwest of the townsite the Reeves limestone on the overturned limb of the Jersey anticline dips less than 45 degrees east and swings to a northeasterly strike. The isoclinal folds east of the limestone plunge southward more steeply than the slope of the hill, so that anticlines with Truman argillite at the core tail out and intervening synclines of the Reeves limestone broaden in outcrop to the south.

North of the Emerald stock the Reeves limestone on the overturned limb of the Jersey anticline forms an isolated wedge between the eastern side of the stock and the Granite fault. Outcrops are scarce near the Main camp and north of it, and although considerable drilling has been done in this area in search of tungsten north of the Granite fault, details of the structure are uncertain. The surface trace of the Granite fault is moderately well defined near the Main camp. Limestone east of the fault resembles the Reeves limestone, and the bands of skarny argillite within it appear to be infolds of the Truman member. Diamond drilling shows that the Emerald black argillite lies under the limestone in depth (*see* Fig. 10, section E-E^1). Foliation in the outcrops dips more than 45 degrees east, but the western contact of the limestone, as determined in drilling, on the average dips only 30 degrees east. The relationships suggest that, in addition to the Granite fault, a gently east-dipping bedding fault lies between the Emerald argillite and the Reeves limestone north of the Main camp.

Structural evidence north as far as Sheep Creek is lacking because outcrops are scarce. North of Sheep Creek on the Black Rock claims a bedding fault is present on the west side of the Reeves limestone (*see* Fig. 7, section B-B^1) in a position similar to that north of the Main camp on Iron Mountain. Possibly a bedding fault separates the overturned part of the Jersey anticline on the east from the recumbent part of the overturned limb on the west for considerable distances.

On the northwest slope of Iron Mountain, bands of limestone and skarn appear to be isoclinal synclines and intervening bands of argillite to be isoclinal anticlines. These folds plunge gently south near the Emerald lead-zinc mine, and about 1,500 feet north of the mine the plunge reverses to gently north. A few of the folds can be seen underground and on the surface above the Emerald lead-zinc mine, but most of them cannot be seen. On the lower slopes, foliation dips steeper than 45 degrees to the east, but higher on the slope the dip flattens and near the dolomite zones both north and south of the Emerald lead-zinc mine the dip is less than 45 degrees. In this area there do not appear to be any bedding faults between the right-side-up limb of the Jersey anticline and the zone of complex isoclinal folds to the west. Nowhere on the surface, however, are the relationships exposed well enough to be certain that bedding faults do not exist. Complex structures seen in the Jersey mine close to and beneath the lead-zinc orebodies to the south suggest the possibility of bedding faults close to the dolomitized zones.

Limestone on the upper part of Iron Mountain characteristically dips gently. Generally the dips are to the east and south, but locally over fairly wide areas they are to the west. At many places the attitudes of banding in individual outcrops are readily seen, but only in areas of almost continuous outcrop can attitudes be integrated and the over-all structure determined. On the open south slope of Iron Mountain, where outcrops are most extensive, panels of limestone with gentle dips and open folds are separated from similar panels to east and west by zones of steep dips and irregular, complex minor folds. The panels of gently folded rock are several tens of feet wide from east to west and much longer from north to south. Open folds within them plunge gently south. The relation between adjacent panels is not always obvious because the steeply dipping sections are complexly folded. In general, bands in one panel appear to be stepped down through an intervening zone of steep dips into the next panel to the east. Thus two adjacent panels and the intervening zone of steep dips together form a Z-shaped fold (*see* p. 50) when seen in section looking north. This pattern of folding is outlined by banding in the limestone.

South of the Jersey townsite the right-side-up limb of the Jersey anticline is formed of Navada quartzite which displays a series of folds subsidiary to the anticline. The quartzite lying between the southern part of the Emerald stock and the Quartzite Ridge is folded into small open anticlines and synclines plunging gently southward steeper than the slope of the hill. A few hundred feet east of the Quartzite Ridge, westerly dips steepen through vertical to steep easterly dips in the form of a large overturned anticline, probably the northern continuation of the Truman anticline (*see* p. 68). The Upper Navada white quartzite on the Quartzite Ridge is folded into a large south-plunging dragfold on the western overturned limb of the Truman anticline. The dragfold is indicated by joints in the quartzite that are steeply dipping on either side of the ridge and are gently dipping near the centre.

Bedding faults in the central part of the Mine Belt and details of the Jersey fault immediately west of the Quartzite Ridge are described on page 73. Two other bedding faults have been recognized in surface mapping on Iron Mountain, and many small bedding faults can be seen underground in the Jersey mine. On surface one fault is a few hundred feet west of the Jersey fault. It is not exposed but has been inferred from the fact that Upper Reno quartzite that dips east and is right-side-up is in contact with Reeves limestone that dips east and appears to be overturned. The fault has been traced for about 3,000 feet south of the Jersey townsite. Near the townsite it appears to joint the Jersey fault.

Another bedding fault known locally as the Emerald fault has been recognized near the Main camp. It separates an eastward-dipping right-side-up sequence of the Reno quartzite and argillite, skarn, and limestone of the Truman member from the Reeves limestone on the west. The limestone is not well exposed and the fault cannot be traced for more than about 1,000 feet northeast of the Main camp. Diamond drilling indicates that it dips 35 to 45 degrees eastward.

A number of transverse faults which cut across the older structures occur in the Jersey mine area. One of the most prominent is the Iron Mountain fault, which has been called the Black Argillite fault by company geologists. It strikes north 20 to 25 degrees east; at the north end of Iron Mountain it is nearly vertical and to the south it dips westward. The fault separates the Active black argillite on the east from rocks of the mine area on the west and is downthrown on the east. It is described on page 62.

A second transverse fault of considerable significance is the Granite fault. It has been traced from near the east end of the Jersey townsite northwest and north along the west slope of Iron Mountain as far as the Main camp. North of the camp it has not been located with certainty because of limited outcrop, but it probably lies east of the small outcrops of granite west of the main road. Through much of its length the fault forms the eastern side of the Emerald stock. In the Jersey and Feeney mines the fault strikes north and dips on the average 40 degrees to the east. It is a normal fault, but the amount of displacement is not known. Estimates based on drill-holes above and below the Dodger 4200 crosscut, from which the position of the roof of the Emerald stock on either side of the fault can be obtained, indicate that the dip slip is greater than 700 feet. The fault zone underground contains a few feet of gouge, and rocks for several feet on either side are strongly shattered.

In addition to these major transverse faults, other smaller faults have been found underground. With the exception of a northwestward trending fault that offsets the Iron Mountain fault east of the Jersey mine (*see* Fig. 9), none of the smaller faults have been found on surface. Some of the faults seen underground are described on page 116.

Jersey

The lead-zinc orebodies in the Jersey mine are gently dipping tabular or lenticular masses of sulphides associated with open folds which plunge gently southward. The orebodies are near the base of the Reeves limestone that underlies the upper part of Iron Mountain. They have been named, from west to east, the A, B, C, D, E, and F zones (*see* Fig. 11). Canadian Exploration Limited began mining on the south slope of Iron Mountain at the outcrop of the B zone in the B zone open pit. Subsequently two adit levels, the 4000 and 4100 levels with portal elevations of 4,010 and 4,080 feet respectively, were driven northward from the south slope of Iron Mountain under the orebodies. Ore was mined in open stopes and moved to the haulage level by scrapers and ore-passes. This conventional track system of mining was continued north a distance of more than 1,000 feet to near the 5000 north co-ordinate, and farther north trackless mining methods have been used, in the course of which most development is in ore and very little exploratory drilling is done. In track mining the haulage levels, raises between them, and stopes permit access not only to the orebodies, but also to the rocks beneath them. The structure of the mineralized zones themselves appears to be simple, but the structure of the underlying rocks is exceedingly complex, and in order to obtain as complete cross-sections as possible the detailed studies of the Jersey ore zones have been made mainly in the track area. Of the six orebodies, the A, B, C, and D have been extensively mined in the track area, and the E and F have been mined only in the trackless area.

The A or most westerly zone has been fully developed from its southern end on the 4000 level near the 4250 north co-ordinate to the old Emerald lead-zinc mine, a distance of nearly 4,000 feet (*see* Fig. 11). Through most of its length the long axis of the A zone strikes due north, but to the north it swings to a few degrees east of north. The average plunge is about 10 degrees south. In cross-section the A zone has a western section as much as 60 feet thick, and an eastern section 10 to 15 feet thick. The western section is between 100 and 200 feet wide from east to west and lenses out to the west. To the east, the upper part of the western section joins the eastern section, but the lower part dies out against a mass of skarn and argillite known in the mine as the "A zone skarn roll." The " skarn roll " continues through much of the length of the A zone (*see* Fig. 11), but dies out north of the 6100 north and south of the 4300 north co-ordinates.

The B zone lies in the trough of an open syncline, the axis of which strikes about north 20 degrees east and plunges gently south. It extends from the B zone open pit to about the 4400 north co-ordinate, a distance of more than 800 feet. The B zone is higher than the A zone, and diverges from it to the north. It is about 250 feet wide and as much as 60 feet thick. On the west, sulphide mineralization dies out rapidly, and on the east it passes through a thin low-grade section into the western side of the C zone. To the north the B zone steepens in plunge and thins abruptly along an axis trending northeast and is cut off by a northwestward trending fault. The B zone is not known to continue to the north.

The C zone through most of its length dips gently westward and has a long axis trending about north 20 degrees east. It does not outcrop between the B and D open pits because it is concealed by a fault known as the Glory Hole fault (*see* Fig. 11). North of the fault it has been developed as far as the 5000 north co-ordinate, a distance of about 1,300 feet. In general, ore in the C zone is 10 to 20 feet thick but in places is 35 feet thick. On the west it passes through a narrow low-grade section into the B zone and on the east it passes similarly into the D zone.

The D zone dips eastward, and the C and D zones together have the form of an open anticline, the axis of which strikes north 15 degrees east and plunges 10 degrees south.

The D zone in general is 10 to 20 feet thick and about 100 feet wide. A thin, sparsely mineralized section on the crest of the anticline between the C and D zones thickens to the east. The thickest section of the D zone is where the eastern limb of the anticline flattens in dip and to the east mineralization dies out rapidly. The D zone has been mined from the D zone open pit on the south slope of Iron Mountain to the 5000 north co-ordinate, a distance of about 1,800 feet.

The E zone occupies a shallow syncline east of the D zone. It has been developed for about 1,800 feet, mainly north of the 4249 crosscut. The long axis of the E zone strikes north 10 degrees east. The ore is about 10 feet thick and lenses out gradually to the east and west. The F zone lies in an easterly dipping series of beds east of, and lower than, the E zone. It has not been extensively mined and little is known of its general form.

The mineralized zones are composed of fine- to medium-grained sphalerite, galena, pyrite, and pyrrhotite disseminated in dolomite. Bands of sulphides, light- and dark-grey dolomite, and streaks of white dolomite in the sulphides give the ore a pronounced banding (*see* Plate XV). The bands range from a fraction of an inch to a few inches wide and tend to feather out along their length. At the edges of the orebodies, sulphides either end abruptly or thin bands of sulphides in dolomite die out gradually. Some of the more abrupt tails have the form of attenuated folds, but most are merely an irregular interfingering of sulphides in dolomite.

In places sulphides occur in breccia. The most important occurrence of this type is near the base of the thick western part of the A zone (*see* Plate XVI). The breccia is made up of angular and poorly rounded fragments of dolomite a few inches across surrounded by massive sulphides, mainly galena. The breccia zone is a few feet thick and, although discontinuous, is present through most of the A zone west of the " skarn roll." Commonly the dolomite fragments are few and small, so that the breccia zone forms a band of lead ore at places several feet thick. This " high lead band " was mined in the old Emerald lead-zinc mine as an eastward-dipping vein. Similar extensive zones of breccia are not found in the other orebodies, but considerable breccia ore is reported to have been mined in the C and D zones.

The ore zones are in dark- and light-grey banded dolomite. The dolomite is mainly in two large lenses—one surrounding the A zone and the other associated with the B, C, D, and E zones. The lenses are 50 to 150 feet thick and extend a few hundred feet east and west beyond the mineralized zones. The orebodies are in the lower half of the dolomite, but scattered mineralization has been found at other places in the dolomite. The most continuous mass of this type of scattered mineralization is above the A zone.* Dolomite entirely surrounds the orebodies, except at the base of the A zone skarn roll where pods of massive sulphides extend a few feet out of the dolomite into the skarn.

The base of the A zone dolomite is within a few feet of the base of the Reeves limestone. To the west at the south end of the mine it is cut off by the Main West fault and Granite fault, and farther north it extends to the surface (*see* Fig. 11). To the east the dolomite probably lenses out beneath the C and D zones.

Dolomite associated with the B, C, and D zones is physically and probably stratigraphically higher in the Reeves limestone than the A zone dolomite. In places near the south end of the mine, between the C and D zones, dolomite lies directly on argillite and skarn of the Truman member, but to the north the dolomite rises, and near the 4249 crosscut it is as much as 200 feet above rocks of the Truman member. Dolomite close to the B and C zones is only a few tens of feet away from the A zone dolomite and in places may join it.

The dolomite lenses out into black- and white-banded limestone which has a more pronounced banding and is somewhat coarser grained than the dolomite. Complex attentuated small folds different from any seen in the dolomite are common in the limestone.

The dolomite and limestone are underlain by a variety of rocks belonging to the Truman member. They include brown micaceous argillite, green and brown banded and mottled skarny argillite, brown garnet skarn, and light-grey or white crystalline limestone. The rocks are complexly contorted. Bands of skarn or limestone in argillite outline folds, many of which have been so modified by the development of skarn that only the most general forms can be distinguished. Beds have been so squeezed and thickened by deformation that a stratigraphic sequence within the member cannot be recognized.

Generally the basal limestone bed of the Truman member can be found and the underlying Upper Reno quartzite is easily distinguished. The quartzite occurs beneath the A zone at the north end of the 4000 and 4100 levels and in the Dodger 4200 crosscut. The quartzite is grey to brown and blocky with closely spaced joints. Beds are difficult to see, but the quartzite does not appear to be as complexly contorted as the overlying Truman member.

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* In 1958 this mineralization was being mined.

The principal structures encountered underground are (*a*) transverse faults, (*b*) bedding faults, (*c*) relatively large open folds, and (*d*) small, exceedingly complex attenuated folds. Many of these structures are shown on Figures 11 and 12, and the following paragraphs refer to these figures, which have been constructed with the aid of company plans and sections. Company drill logs were used because the cores have been destroyed. Mineralized zones in Figure 12 are generalized because most of the ore has either been taken out or is not exposed. The geology has been studied and the sections drawn for the purpose of determining structural patterns and to check their continuity across a section and from one section to the next. Small attenuated folds and complex variations in lithology in the Truman member cannot be shown on the sections and so have been generalized.

The principal transverse faults in the Jersey mine are shown in Figure 11, together with their dip and estimated dip slip. No well-defined pattern of faulting has been recognized. In general, faults strike north or northwest and dip steeply, commonly to the east. They are mainly downthrown on the east, but the Adie fault and another in the E zone are downthrown on the west. The dip slip has been estimated by matching ore zones on either side of the faults. Slickensides on the A zone and Glory Hole faults are more or less parallel to the dip, and although the strike slip has not been determined the greater component of movement on these faults, and probably also on the others, is dip slip. The faults appear to be later than the ore. Slickensided sulphides occur along the A zone fault at the north end of the B zone stopes. Breccias on the Glory Hole, A zone, and Adie faults contain angular fragments of banded ore in a matrix containing only minor amounts of sulphides. They contrast with the A zone breccia ore which is localized on pre-ore faults and in which the matrix is massive sulphide and the fragments mainly dolomite. The faults offset the ore, but orebodies on one side of a fault cannot in general be matched in thickness and detailed characteristics with those on the other. Because of these relationships the mine geologists have thought from time to time that the faults may pre-date the ore and may have exercised some control on mineralization. Evidence is convincing, however, that several faults are later than the ore, and no obvious relationship of ore to steeply dipping faults has been established.

Gently dipping faults more or less parallel to the bedding occur in the ore zones and in the rocks beneath them. The faults are sharply defined planes along which beds are transected at an acute angle. Signs of brecciation and shearing are rare. The faults tend to die out or to become strictly bedded in relatively short distances, and cannot be traced or projected far. A few of the faults are strongly curved and may have been folded. Sulphides and masses of skarn are found along some of the fault planes, but at least one gently dipping fault appears to cut the ore. None of these faults has been named, and several that are shown on Figure 12 are referred to in succeeding paragraphs.

Two of the most significant folds in the Jersey mine are the A zone skarn roll and the anticline between the C and D zones. The A zone skarn roll, seen in section looking northward (*see* Fig. 12), through most of its length is an S-shaped fold (*see* p. 50) with a short, steeply dipping section convex to the west between two extensive, gently dipping limbs. The thick western part of the A zone in many stopes terminates on the east against green and brown skarny argillite on the steeply dipping part of the roll. The argillite dips west near the top of the roll and steepens downward through vertical, commonly to a steep easterly dip. These steeply dipping beds lie above gently dipping beds, and the two either join in a sharp crease or are separated by a gently east-dipping fault. The shape of the skarn roll as seen in the east walls of stopes on the western part of the A zone is fairly constant for several thousand feet along its plunge, but complete sections of the fold are rarely seen, and the shape of the mass of skarny argillite east of the stopes may vary considerably. The only two complete sections seen by the writers are shown in Figure 12. In section E-E^1 the convex western face of the skarn and argillite is exposed in the east wall of the 48A2 stope, and the gently dipping fault and two tails of argillite are seen in a manway a few feet south of the section. Massive galena and sphalerite extend along the fault a short distance into the argillite, and the fault, projected westward, contains massive galena in breccia ore in the 48A1 stope. Banding in the ore immediately west of the skarn and argillite steepens gradually over the fold but in general dips less steeply than the surface of the skarn and argillite. Lower bands tend to butt into the skarn and argillite to the east and upper bands pass over the fold with only a gentle flexure. Complex minor folds that might be expected in the ore close to the fold are rarely seen. The main structures on section E-E^1 are typical of the A zone for a few thousand feet to the north, but the tails of argillite probably change in shape.

To the south, on section D-D^1, the shape of the skarn roll is entirely different to that on section E-E^1. Two eastward-dipping faults on either side of a mass of greenish skarn and argillite are exposed in one wall of the 4045 stope and in the ore-pass to the east just south of the section. The upper fault is also exposed in the 4146 crosscut. The skarn and argillite feather out into mineralized dolomite in the wall of the stope. Structure in the dolomite is simple, and neither of the faults can be seen in the ore. Banding in the ore is uniform and gradually fades out a few inches from the skarn and argillite. Local high concentrations of sulphides continue eastward a few tens of feet beneath the skarn.

The anticline between the C and D zones is a relatively persistent structure with an axis striking north 15 degrees east and plunging south at about 10 degrees. The structure is a simple open fold in the ore and adjacent dolomite, but it does not continue as a simple structure into the argillite beneath the ore. It is complicated by bedding faults, minor folds, and irregular masses of skarn. From about the 4300 north co-ordinate southward the ore is relatively close to argillite and skarn, but to the north where the argillite is cut out, probably by bedding faults, the ore has a much greater thickness of limestone and dolomite beneath it.

The anticline between the C and D zones is known from several fairly complete cross-sections, one of which is section B-B^1 along the 4142 crosscut. Green and brown skarny argillite forms the core of the anticline. On the east beneath the D zone the argillite dips gently south and east, and to the west the easterly dip gradually steepens to nearly vertical in the manway below the 4142 stope. The argillite is crowded with small dragfolds which are Z-shaped in section. The dragfolds vary in attitude with the dip of the beds. The argillite in the manway is in fault contact with the overlying dolomite, and at the bottom of a chute near the east end of the crosscut it is in fault contact with green skarn. The argillite is followed on the west by limestone with minor skarn and dolomite dipping east and steepening in dip upward.

The C and D orebodies, by their shape and the attitude of banding within them, form an asymmetric anticline. The structural complexities which occur in the underlying skarny argillite do not occur in the orebodies or in the dolomite adjacent to them. The relationship between the complex structures in the argillite and the apparently simple structure of the orebodies is uncertain. Probably the apparently simple anticline is a composite structure in which gently dipping faults separate steeply dipping from gently dipping beds. Many gently dipping faults that can be seen along contacts of limestone or dolomite with argillite and skarn are obscure within the limestone and dolomite.

Argillite seen in the core of the anticline of the C and D orebodies on section B-B^1 does not continue to section C-C^1, less than 200 feet to the north. Direct evidence is lacking, but it seems probable that the argillite is cut out by gently dipping faults. On section C-C^1 the anticline is outlined by the orebodies and by limestone and dolomite and has the same general characteristics as on section B-B^1. Banded limestone beneath the ore dips steeply eastward on the 4145 crosscut and flattens toward the east. Attenuated small dragfolds in the limestone are Z-shaped in section and follow the banding in the same way as those in the argillite on section B-B^1. Gently dipping minor faults can be seen along the limestone-dolomite contact in the 4145 crosscut, but gently dipping faults have not been found elsewhere. Despite this fact it is probable that bedding faults are present within the anticlinal structure in section C-C[1] as they are to the south.

To the north, little is known of the details of the anticline. On section E-E[1] about 200 feet of limestone and dolomite lie between the orebodies and the skarn and argillite of the Truman member. Where exposed on the 4249 crosscut, the anticline is more open than it is to the south.

South of section B-B[1] the anticline has the same general features as to the north but is complicated by transverse faults and irregular masses of skarn. One such mass is shown on section A-A[1] below the C zone. It is massive green skarn made up mainly of very fine-grained pyroxene. It probably grades westward into a micaceous brown dolomite associated with the B zone.

The foregoing descriptions of the significant structures in part of the Jersey mine have been given to show the problems involved in interpreting structural detail and in determining ore controls. Although the general structural setting of the orebodies is known, and it is certain that the orebodies are structurally controlled, structural detail seen underground is difficult to interpret and unifying patterns of ore control are not obvious. Underground workings display in ore and surrounding rocks a host of features the significance of which is rarely apparent. The following generalizations are made in the light of extensive detailed studies and a knowledge of the regional relationships.

(1) Essentially all the brown argillite (and the skarn and limestone within it) is part of the Truman member and stratigraphically underlies the Reeves limestone. Tails and isolated masses of argillite such as those in the A zone skarn roll are remnants of the Truman member infolded in the Reeves limestone. They probably originated as isoclinal anticlines that were subsequently sheared and folded.

(2) The structural sequence is important in understanding which of the many structures control mineralization. Primary folds are represented by tails (*see* p. 70) and lenses of argillite, skarny argillite, and certain types of skarn in the Reeves limestone and by small highly attenuated dragfolds in the skarny argillite and limestone. The large primary folds can rarely be seen, but small primary folds are evident at many places and include the Z-shaped dragfolds described previously (*see* p. 117). The axial planes of these dragfolds follow banding of the rocks; where banding dips steeply the axial planes are steep, and where banding dips gently the axial planes dip gently. The attitude of the banding outlines secondary folds and the primary folds have been folded. The anticline between the C and D zones and the A zone skarn roll are in part secondary folds.

Characteristics of the bedding faults suggest that movement on them extended over a relatively long period of time. Many bedding faults are mineralized with sulphides and lime silicates and are obscured by recrystallization of limestone and dolomite. Many are therefore old and probably were developed at a late stage of the primary isoclinal folding. Some of the faults appear to have been gently folded (*see* Fig. 12, section D-D[1]), although they do not conform to known secondary folds. Locally bedding faults transect the ore, and movement on them has been later than the sulphides. It is suggested that movement on bedding faults continued through a period which extended from late in the primary folding until after the secondary folding.

Transverse faults are later than the primary and secondary folds and the bedding faults, and many are later than the ore.

(3) The dolomite is an epigenetic replacement of the limestone that is closely associated with the development of the sulphides. The dolomite has been cut by the Emerald and Dodger stocks and has been thermally metamorphosed. The contrasting rock types produced by metamorphism have no stratigraphic significance and may obscure structures. Study of the metamorphic rocks has not been detailed enough to permit separation of all skarns derived from dolomite from those derived from other calcareous rocks, but two distinctive alterations of dolomite have been recognized. One is a light-green massive rock that resembles chert and is composed of very fine-grained diopside. The other is known locally as brown argillaceous dolomite and is dolomite with bands containing several varieties of mica.

(4) Primary dragfolds in rocks beneath the C and D zones and above and east of the A zone suggest that these rocks are overturned. The stratigraphic sequence below the A zone is right-side-up. The implication of these two facts is that the A zone is on a different primary fold than the C and D zones.

(5) Bedding faults and secondary folds are probably the most important structures controlling mineralization. Galena-rich breccia ore in the A zone appears to occur along a bedding fault. Locally, bedding faults at some distance from the orebodies contain sulphides. Most bedding faults are obscure in dolomite and in the ore zones so that evidence of their importance must be inferred. The importance of secondary structures is shown by the fact that the A zone follows the A zone skarn roll and the B, C, and D zones are related to the anticline between the C and D zones. Both are secondary folds. Their significance in controlling mineralization is imperfectly known, but there is little doubt that mineralization is genetically related to them.

Emerald, Feeney, Dodger

The Emerald, Feeney, and Dodger are tungsten mines. The Emerald has been the principal producer (*see* p. 107), the Feeney operated between 1951 and 1955, and the Dodger between 1951 and 1958. All tungsten production ceased in 1958 when sales contracts with the United States Government came to an end. Production to the end of 1957 amounted to 1,003,317 tons of ore yielding 13,048,963 pounds of tungstic oxide. Of this, about 60,000 tons of ore came from the Feeney and 285,000 tons from the Dodger mine.

Tungsten mineralization has not been studied in the present work. Detailed accounts of the geology of the tungsten mines are given by Hedley (1943), Ball *et al.* (1953), and Rennie and Smith (1957). The following notes describe briefly the general location of the tungsten orebodies in relation to the general geology of Iron Mountain.

Tungsten mineralization consists of scheelite disseminated through skarn and other metamorphic rocks associated with the Emerald and Dodger stocks. Scheelite is the main tungsten mineral, but small amounts of powellite ($Ca(MoW)O_4$) and rare wolframite ($((FeMn)WO_4)$) are reported. Characteristically the skarn is a green and brown granular rock containing diopside, garnet, and more or less calcite. In the Emerald and Feeney mines, skarn containing augite, actinolite, epidote, pyrrhotite, and locally quartz is common. Scheelite occurs also in granular rocks composed of varying amounts of pyrrhotite, pyrite, quartz, and biotite. The sulphides may be the chief constituent of such rocks or quartz may predominate. Scattered flakes of molybdenite are found in much of the skarn.

Tungsten orebodies in the Emerald mine are on the western side of the Emerald stock. They occur at and near the contact of the granite and the upper part of the Reeves limestone on the overturned limb of the Jersey anticline. Scheelite is found along the granite-limestone contact which dips steeply west and along the contact between the limestone and the Emerald argillite which dips to the east and is overturned. The mineralization is in a long trough-shaped zone with low plunge known as the Emerald "tungsten trough." Ideally, orebodies are V-shaped in cross-section with a westerly dipping eastern limb along the granite-limestone contact and an easterly dipping western limb along the limestone-argillite contact. In actuality the orebodies are very irregular in cross-section because of irregularities both in the granite contact and in the vagaries of replacement. Near the base of the trough the ore is a few tens of feet thick and on the limbs it is considerably thinner. Ore may continue up one or both limbs distances as great as 200 feet. The trough plunges to the south at angles controlled by the configuration of the Emerald stock and the dip of the limestone-argillite contact. In the northern part of the mine the plunge is less than 20 degrees to the south and in the southern part it steepens to greater than 30 degrees. The Emerald tungsten trough has been mined from its outcrop, at an elevation of about 4,100 feet, southward for a distance of a little more than 3,000 feet down the plunge. Drilling south of the mine indicates that it continues at least another 1,000 feet to the south, where it is at an elevation of about 2,500 feet.

The tungsten orebody in the Feeney mine is on the east side of the Emerald stock north of the northern end of the Emerald mine. Mineralization is in the same structural position as that in the Emerald trough on the east side of the stock. Scheelite occurs in a relatively small shallow orebody along the contact between the Reeves limestone and the Emerald argillite and along the contact between the limestone and the stock. The limestone-argillite contact dips to the east; the granite-limestone contact is highly irregular but in general is gently dipping. Both these contacts and the orebodies associated with them are transected on the east by the Granite fault (*see* p. 113 and Fig. 9).

Diamond drilling east of the Granite fault has located scheelite in a zone that appears to be the northern extension of the Emerald and Feeney zones. This zone, called the Invincible trough, occurs where the Reeves limestone and Emerald argillite on the overturned limb of the Jersey anticline are cut by the western side of the Dodger stock. Section E-E^1 in Figure 10 shows a row of holes drilled to test the Invincible trough. Scheelite was found in skarn along the intersection of the western side of the Dodger stock and the limestone-argillite contact. The zone is 800 to 900 feet below the surface, strikes northward, and has been tested for a few thousand feet along strike. According to company reports, 386,000 tons grading 0.83 per cent tungstic oxide are indicated. In 1957 preparations for mining were started but were not continued because of the unfavourable market for tungsten.

The Dodger mine is east of the Emerald and Feeney mines and in general north of the Jersey. In the Dodger orebodies scheelite occurs in skarn near the base of the Reeves limestone close to the Dodger stock. Skarn and skarny argillite are in the Truman member and only locally has skarn developed in the Reeves limestone. The Truman member is complexly infolded with the lower part of the Reeves limestone. The rocks are on the right-side-up limb of the Jersey anticline and occupy the same structural position and show the same pattern of primary and secondary folds as those beneath the Jersey orebodies to the south (*see* p. 116 and Fig. 10). Scheelite is found near the irregular upper surface of the Dodger stock. Near the Dodger 4400 portal and for considerable distances to the south the orebodies are in a trough in the granite surface. Farther south the trough is less pronounced and the orebodies are on the western side of a ridge of granite. These general relationships are shown in Figure 10, sections E-E^1 and D-D^1. The orebodies are very irregular in shape and attitude. In general they are along a zone plunging gently to the south and extending from near the 4200 crosscut to the 4400 portal, a distance of about 4,000 feet. Within the zone, relatively small orebodies occur intermittently.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1908, p. 246; 1911, p. 284; 1913, p. 131; 1914, p. 328; 1915, p. 162; 1947, p. 163; 1948, p. 135; 1949, p. 168;

1950, p. 126; 1951, p. 140; 1952, p. 147; 1953, p. 117; 1954, p. 126; 1955, p. 51; 1956, p. 80; 1957, p. 44; Ball *et al.*, 1953, p. 471; Hedley, 1943, p. 135; Little, 1953, p. 468; McCutcheon *et al.*, 1954, p. 398; Rennie and Smith, 1957, p. 116; Walker, 1934, pp. 54–57; Walkey and Little, 1954, p. 376.]

Jack Pot

The Jack Pot property comprises sixteen recorded claims on the south side of Porcupine Creek between two groups of Crown-granted claims—the Eldorado and Carmencita on Active Creek and the Hunter V, Double Standard, and Mercia on the ridge between Porcupine Creek and Hidden Creek (*see* Fig. 3). All the claims are owned by New Jersey Zinc Exploration Company (Canada) Ltd., company office, 525 Seymour Street, Vancouver.

Mineralized zones on the Jack Pot claims, called the East, Lerwick, Main, and West zones, consist of disseminated sphalerite, galena, and iron sulphides in dolomite. They are reached by a switchback road 4 miles long that leaves the Porcupine Creek road about 400 feet west of Active Creek and climbs southward to the ridge between Porcupine and Hidden Creeks.

The East zone is exposed by trenches and road cuts between elevations of 4,300 and 5,100 feet* on the steep slope west of Spot Creek crossed by the switchback road (*see* Fig. 8). The Lerwick zone in the vicinity of the old Lerwick shaft is exposed by bulldozer cuts between elevations of 5,600 and 5,800 feet on the same slope. The Main zone between elevations of 5,400 and 5,600 feet is on the steep north-facing slope of the hill about 1,500 feet northwest of the Lerwick shaft. The hill is referred to in this report as the Jack Pot Hill. The Main zone is exposed in surface trenches and by an old adit. The West zone, at an elevation of 5,600 feet, is 1,000 feet southwest of the Main zone and is exposed by trenches. The four zones have been diamond drilled from surface, and on the East zone two adit levels have been driven at elevations of 4,100 and 4,400 feet, from which additional diamond drilling has been done. Buildings on the property include a core shed and four frame buildings near the portal of the 4100 level adit and a core shed west of the Lerwick zone near the top of the Jack Pot Hill.

Workings on the Crown-granted claims include an open pit on the Hunter V and a large glory-hole on the Double Standard claim. An old prospect adit on the south bank of Active Creek is on the Eldorado claim.

The Jack Pot claims were located by E. H. Barclay, S. W. Barclay, and E. P. Haukedahl in 1948. Although very little is known of previous work on the property, numerous workings, some of which are probably more than fifty years old, give evidence of early activity. Much of the ground now covered by the Jack Pot claims was held by old Crown-granted claims that have since been cancelled. Of these, the Lerwick, Hercules, and Big Four were located in 1896. The Balsam group of five claims, now lapsed, was located by E. P. Haukedahl and partners in 1942 to cover scheelite showings on the southern part of the present Jack Pot property.

The New Jersey Zinc Exploration company took the Jack Pot claims under option late in 1948 and has since purchased the property. In 1949 the company built the road from the Porcupine Creek road to the main mineralized zones on the Jack Pot Hill and started a programme of trenching, bulldozer stripping, and diamond drilling. A geological map of the property was made on a scale of 100 feet to 1 inch, and a geophysical survey was made near the mineralized zones. In 1951 the 4400 level adit was driven on the East zone and diamond drilling was done from it. In 1953 the 4100 level adit on the East zone was started and the 4400 level was advanced. Both adits were completed and diamond drilling was done from them in 1954. No work has been done on the property since.

The Hunter V, Double Standard, and Mercia claims that join the Jack Pot group on the west were Crown-granted in 1902. British Columbia Standard Mining Company mined mineralized limestone on the Hunter V and Double Standard claims in 1903.

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* Elevations refer to contours of Figure 8.

1904, and 1905 and made shipments to smelters at Trail, Nelson, Northport, and Grand Forks. The limestone was mined primarily as smelter flux but carried several ounces per ton in silver. Hall Mining and Smelting Company, Limited, mined on the claims for flux during 1905, 1906, and 1907, and the Consolidated Mining and Smelting company mined from 1925 to 1929. No work has been done since 1929. Production from 1902 to 1929 totalled 62,634 tons of limestone and yielded: Gold, 1,010 oz.; silver, 272,141 oz.

The Eldorado and Carmencita claims that join the Jack Pot group on the northeast were Crown-granted in 1902 and 1903 respectively. There is one short adit and a number of pits in mineralized dolomite on the Eldorado claim, but no published record of this work has been found.

STRATIGRAPHY

The stratigraphy of the Mine Belt in the Porcupine Creek area is described in Chapter II, and the basis of correlations of the rocks with the Quartzite Range, Reno, and Laib formations is given. The stratigraphy and structure are moderately well understood on the Jack Pot property in the vicinity of the East zone but are not understood on the remainder of the property. The East zone is isolated from the rest of the property by an area with very few outcrops, and the two areas are given separate descriptions.

East Zone

An incomplete stratigraphic section from Navada quartzite to Reeves limestone occurs in the vicinity of the East zone but is not exposed as a simple sequence. Reeves limestone underlain by the Truman member and Upper Reno quartzite form the isoclinal Jack Pot syncline (*see* p. 74) containing the East zone mineralization. Parts of the Lower Reno and of the Navada quartzite lie west of the syncline on the eastern limb of the Jack Pot anticline (*see* p. 73). The Active formation lies east of the syncline.

The Navada quartzite is well exposed on the slope northwest of the Jack Pot road. The Lower Navada is mainly micaceous grey and brown quartzite with minor narrow beds of white quartzite. The Upper Navada is blocky white quartzite as much as 200 feet wide exposed between elevations of 4,000 and 4,500 feet. Reno quartzite lying east of the Navada quartzite outcrops poorly but is exposed in two switchbacks of the Jack Pot road. The rock is grey micaceous quartzite with layers of grey to black phyllite. Only the lowermost beds of the Reno formation are found on surface on the west side of the Jack Pot syncline. The Upper Reno quartzite has been recognized in drill cores on the west limb of the syncline and is exposed in the 4100 and 4400 levels and on surface on the east limb of the syncline. The quartzite in general is grey and blocky but in part is brown and micaceous. The grey beds locally have a greenish cast caused by a small proportion of diopside between the quartz grains. Both the Lower and Upper Reno, though incomplete and not found in sequence on the Jack Pot property, are typical of the Reno formation elsewhere in the Mine Belt.

The Truman member overlies the Reno quartzite on the limbs of the Jack Pot syncline and is well exposed underground and on the switchback road. It includes brown biotite hornfels and white and brown micaceous limestone. The hornfels is in places altered to a green and brown or green and white banded rock composed mainly of diopside. The limestone is locally altered to skarn. The thickness of the Truman member varies widely in different parts of the syncline but averages less than 50 feet. Limestone and dolomite of the Reeves member occur at the core of the Jack Pot syncline and are moderately well exposed on the steep wooded slope west of Spot Creek. They are found through most of the 4400 adit and for short distances in the 4100 adit. Both dolomite and limestone are typically grey and white banded rocks, but the dolomite in general is finer grained and less well banded than the limestone. On weathered surfaces much of the dolomite crumbles and weathers to a dolomite sand.

The Active formation is in fault contact with calcareous beds of the Truman member along the east limb of the Jack Pot syncline. The contact is exposed in the 4100 and 4400 level adits, at a few places on the switchback road, and was encountered in a number of drill-holes. Outcrops of the Active formation are scarce on the slope west of Spot Creek, and the rock types are known mainly from drill cores. Three fairly continuous rock units can be distinguished. The unit on the west along the fault is black carbonaceous argillite, most of which is only slightly calcareous. It is about 100 feet thick and is succeeded on the east by about 100 feet of a distinctive grey and white dolomite with black irregular streaks. East of the dolomite is mainly black argillite, which in part is calcareous and near Spot Creek is interbedded with minor grey limestone and dolomite.

Lerwick, Main, and West Zones

The stratigraphic units of the East zone are probably represented in the vicinity of the Lerwick, Main, and West zones, but lithologic correlations are made difficult because the rocks have been changed by thermal metamorphism and granitization and only fragments of normal stratigraphic sequences can be found. Most of the limestone and dolomite exposed from the Lerwick zone to the Double Standard glory-hole is believed to be the Reeves limestone. It is the same typical grey and white banded rock that contains the East zone, and locally it is associated with rocks like those of the Truman member and Reno formation. Elsewhere, as east of the Lerwick zone and south of the large diorite body on top of the Jack Pot Hill, limestone and dolomite are in apparently conformable contact with black argillite. The argillite may be part of the Active formation which is in fault contact with or the Emerald member which stratigraphically overlies the Reeves limestone. Both limestone and dolomite are locally coarsely crystalline and contain scattered metamorphic silicates. Limestone is mainly altered to wollastonite and tremolite, whereas dolomite is altered to diopside, tremolite, and forsterite.

The Lower Navada micaceous quartzite outcrops continuously from north of the East zone to the vicinity of the Main zone, and narrow white beds can be traced as markers over much of this distance. Above 5,400 feet elevation the quartzites are rich in biotite and become progressively more granitized toward the west. Beds of white quartzite have not been as thoroughly granitized as the micaceous rocks, but are nevertheless difficult to trace on bluffs north of the Main zone. In Figure 8 the quartzitic rocks to the north, east, and south of the Main zone are shown as belonging to the Navada member, but they may include some Reno quartzite. The quartzite north of the Lerwick zone and the one isolated outcrop between the Lerwick and East zones are white quartzites and micaceous quartzites like those of the Navada member.

Relatively large areas between the top of the Jack Pot Hill and the Double Standard glory-hole have been mapped as mixed rock types and include white, micaceous, and granitized quartzites and minor limestone, black argillite, granite, and diorite. The sedimentary rocks are probably correlatives of parts of the Quartzite Range, Reno, and Laib formations, but metamorphism and structural complexity prevent positive correlation. Sedimentary characteristics and at many places secondary foliation are obscure, and rock units can be traced for only short distances. Between the top of the Jack Pot Hill and the West zone the " mixed rock types " include granitized white quartzite, black argillite, and complexly infolded limestone and brown argillite. South of the West zone the " mixed rock types " are mainly micaceous quartzite with minor infolded hornfels and limestone. On the ridge north of the Hunter V open pit the rocks are mainly white quartzite and black phyllite and argillite. Much of the quartzite is probably silicified phyllite or argillite (*see* p. 40).

The Jack Pot property is immediately north of the Hidden Creek stock, and most outcrops south of Figure 8 are of granitic rocks (*see* Fig. 3). Bodies of diorite and granite related to the stock occur near the top of Jack Pot Hill. Most of the diorite is in two bodies—one south of the Main zone and one west of the Lerwick zone. Granite is more widespread than diorite, but most bodies of granite are too small to be shown in Figure 8. They form dykes, sills, and irregularly shaped masses, a high proportion of which are in the quartzitic rocks or have been mapped with the "mixed rock types." Near the East zone, granite is found only in small dykes in the underground workings.

STRUCTURE

Only the structure near the East zone on the Jack Pot property is understood. The Jack Pot anticline (*see* p. 73), which dominates the structure of the Porcupine Creek area, is west of the East zone and north of the Main and West zones. The anticline is flanked on the east by an isoclinal syncline, the Jack Pot syncline, which contains the East zone mineralization. The syncline is a primary structure cut by bedding faults and is secondarily folded. Above elevations of about 5,200 feet the structure is unintelligible, largely because of complexities related to the Hidden Creek stock. Metamorphism has made stratigraphic correlations uncertain, and structures associated with granitic intrusion are superimposed on complex primary and secondary structures. Rock units are discontinuous and lens out at the crests and troughs of folds by squeezing or by shearing. Many contacts represent faults which are obscure.

The Reeves limestone occupies the core of the Jack Pot syncline, and the Truman member is repeated on the limbs. The axial plane strikes about north 20 degrees east and in general dips steeply eastward, but between elevations of about 4,000 and 4,400 feet it dips westward. The axis is essentially horizontal. To the west the syncline is truncated by a bedding fault separating the Reeves limestone and Truman member from quartzites of the Reno formation and Navada member. The syncline cannot be traced to the south or to the north because of overburden, but it is known to continue southward as far as the south end of the 4100 level. The strike of the formations and probably that of the axial plane of the syncline near the south end of the 4100 level is about north 10 degrees west.

To the east the syncline is followed by what appears to be a small isoclinal anticline in rocks of the Truman member and upper part of the Reno formation. The anticline is inferred from the fact that rocks of the Truman member are repeated on either side of rocks of the Upper Reno formation. The anticline is isoclinal and highly attenuated. The axial plane is parallel to that of the Jack Pot syncline, and the plunge is probably almost horizontal. The anticline is truncated on the east by the Argillite fault.

The change in the dip of the axial plane of the Jack Pot syncline and of the anticline east of it is a gradual one, outlined by changes in the dip of foliation and formational boundaries. The regional dip is steep to the east, but between elevations of about 4,000 and 4,400 feet it is to the west at angles as low as 25 degrees. The syncline and anticline have been folded into a structure with a relatively short west-dipping section between two extensive east-dipping sections. The syncline and anticline are primary folds, and the change in dip of their axial planes resembles a secondary fold. The axis of the secondary fold appears to be nearly horizontal.

The Argillite fault east of the Jack Pot syncline is a regional thrust fault on the east side of the Mine Belt (*see* p. 56). Near the East zone on the Jack Pot property it is bedded, and separates rocks of the Truman member from black argillite of the Active formation on the east. The fault is exposed on the 4400 level and at two places on the 4100 level. On the 4100 level about 600 feet from the face the fault is parallel to banding in rocks on either side of it, and limestone in the Truman member is streaked out and contains black and dark grey eye-shaped masses several inches across. Near the portal of the 4100 and 4400 levels several narrow shear zones occur in the Active argillite near the fault. In general, however, the fault cannot be recognized in individual exposures. The Argillite fault dips steeply eastward and locally dips westward. It has been folded on the secondary fold just described.

The fault west of the Jack Pot syncline is exposed only on the road northwest of the 4100 level portal. The fault separates the Reeves limestone from the lower part of the

Reno quartzite on the west. To the south the fault cuts through the Reno and Upper Navada quartzite into the Lower Navada on its western side and from the Reeves limestone into the Truman member on its eastern side. On the road the fault strikes north and dips steeply west, but farther south it probably dips steeply east following the regional dip of the formations.

Several transverse faults have been encountered in the underground workings, but none has been found on surface near the East zone.

The relationship between the Jack Pot syncline and the complex structures between the Lerwick zone and the Double Standard glory-hole cannot be studied because of a covered area north and east of the Lerwick zone. The formational strike changes in going south from the East zone from east of north, through north to west of north. This change in strike can be seen in the 4100 level and in quartzites above elevations of about 5,200 feet on the ridge west of the Jack Pot road. The change in strike is typical of changes in strike found elsewhere near the Hidden Creek stock (*see* p. 77). It is part of a cross-fold involving primary and secondary folds and bedding faults. Because of the change in strike, structures near the East zone do not continue southward to the Lerwick zone.

Few generalizations can be made regarding the structure between the Lerwick zone and the Double Standard glory-hole. The average strike of the limestone is eastward, and the dip is to the south. The attitude of foliation in adjacent rock types is commonly discordant, suggesting that many contacts are faults. Apparently concordant contacts may also represent faults, judging from the apparent stratigraphic relationships. Only the most prominent faults are shown in Figure 8.

The Reeves member near the Main zone strikes about north 70 degrees west and dips gently to the south. It is bounded on the north by quartzite of the Lower Navada member, and by granitized quartzite. The contact appears concordant but probably represents a bedding fault. Relationships between the Reeves member and the quartzitic rocks to the south are uncertain.

The Reeves member in the Lerwick zone is intruded on the west by a thick diorite dyke. Contacts of the member with other rocks all probably represent faults. Most of the contacts are discordant. Correlation of black argillite on both sides of the southern part of the limestone with the Active formation and of the quartzite to the north with the Navada member suggests that there are pronounced stratigraphic breaks along the contacts. Limestone west of the diorite dyke strikes east and dips steeply south. Farther west it swings in strike to the northeast and in dip to steeply southeast. Near its western edge the limestone contains a band of black argillite in which vertical foliation strikes north 20 degrees east. The structural and stratigraphic relationships between this argillite and the Reeves member are not understood. " Mixed rock types " to the west also strike north 20 degrees east and have vertical foliation. They contain attenuated isoclinal infolds of limestone in quartzitic and hornfelsic rocks. The Reeves limestone south of the West zone dips gently southeast in marked contrast to the attitude of the " mixed rock types " to the east and south.

The limestone is truncated on the west by a transverse fault which has been traced several thousand feet to the north. The fault strikes north, dips steeply, and near the West zone has a small offset. West of the fault a large mass of limestone containing the Hunter V open pit dips gently to the south. Open folds plunge southward and southeastward, and the strike swings to almost northwest near the Double Standard glory-hole. Relationships of the limestone to the surrounding rocks are obscure.

MINERAL DEPOSITS

Four zones of sulphide mineralization—the East, Lerwick, Main, and West zones—occur on the Jack Pot property. All contain predominantly sphalerite with pyrite and very minor galena. Mineralization is restricted to zones of dolomite in Reeves limestone, although locally sulphide minerals occur in calcite within the dolomite zones.

The East zone occurs in dolomite at the core of the Jack Pot syncline. The greater part of the Reeves member in the Jack Pot syncline is dolomite, but bands or zones of limestone occur within the dolomite. The distribution of dolomite and limestone is not known in detail, but the dolomite appears to have the same general form as the Jack Pot syncline. Sulphides are widely distributed through the dolomite and have not been found in the limestone. The best mineralization occurs at an elevation of about 4,400 feet, where the dip of the axial plane of the Jack Pot syncline changes from east to west. Information regarding this sulphide zone is mainly from drill cores, and the attitude of sulphide bands is uncertain. If the sulphides lie parallel to banding in the dolomite, the sulphide zone totals more than 100 feet thick. The zone comprises bands containing disseminated sphalerite alternating with barren dolomite. The bands are as much as 10 feet thick and range in grade from 3 to 15 per cent zinc.

The Lerwick zone east of the top of the Jack Pot Hill consists of sphalerite, pyrite, and pyrrhotite in a uniformly west-dipping dolomite zone. The zone is extensively oxidized at surface and in diamond-drill holes as much as 300 feet below surface. Sulphide layers, more massive than those in the East zone, strike northward and appear to dip westward parallel to the attitude of the dolomite. Mineralized bands as much as 10 feet wide, alternating with wider bands of barren dolomite, outcrop over a width of 250 feet and have been traced on strike for about 500 feet. Individual sulphide bands are not known to continue for more than 100 feet on strike.

The Main zone is well exposed on the steep northwest-facing slope of the Jack Pot Hill and has been explored to the southwest by about twenty diamond-drill holes. Minerals include sphalerite, pyrite, pyrrhotite, and minor galena in somewhat serpentinized dolomite. Tremolite and diopside are locally abundant in the mineralized dolomite. Sulphide minerals appear to follow banding in the dolomite, which dips gently southward on the average but is locally steep and complexly folded. The zone, as outlined by diamond drilling, plunges south 25 degrees west at a low angle, parallel to the plunge of complex minor folds seen on surface.

The West zone, about 1,000 feet west of the top of the Jack Pot Hill, is exposed in trenches for about 450 feet along strike. The zone strikes northeast and probably dips southeast parallel to the dip of the enclosing dolomite and of the limestone to the south. Mineralization is near the base of the dolomite along the northwest margin of a large, gently dipping mass of limestone. In the mineralized zone sphalerite and pyrite occur in banded serpentinized dolomite, and locally sphalerite and minor galena are found in a skarn composed mainly of diopside. The zone has a maximum width of about 8 feet. A row of diamond-drill holes about 200 feet southeast of the showings intersected dolomite but encountered only sparse mineralization. Dolomite of the West zone is truncated by a northward-trending transverse fault. Dolomite west of the fault, which may be the faulted extension of the West zone dolomite, contains scattered sulphides, mainly sphalerite.

Little is known of mineralization in the Hunter V open pit and Double Standard glory-hole. Limestone, mined before 1929 as smelter flux, contained a few ounces per ton of silver. Fine-grained sphalerite, galena, pyrite, tetrahedrite, and native silver are reported. Essentially no sulphides can be seen in the old workings.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1948, p. 132; 1949, p. 165; 1950, p. 122; 1951, p. 136; 1952, p. 145; 1953, p. 115; 1954, p. 125; Walker, 1934, pp. 64 and 65.]

Jumbo

The Jumbo group consists of three Crown-granted claims—the Jumbo No. 1, owned by Alma M. Lincoln, of Tucson, Arizona, and the Jumbo No. 2 and Boncheer, owned by Alice Hearn, of Salmo. The group is on the south slope of Nevada Mountain a little more than 1 mile east of the Jersey mine. The main workings, which include several old pits and trenches and two adits, are along the western contact of the Lost Creek stock between elevations of about 5,000 and 5,300 feet. Many of the workings were made before 1918 to explore pyritic quartz veins containing gold and silver. In 1942 some exploration of the showings for tungsten was done by Kelowna Exploration Company Limited.

The rocks along the western contact of the Lost Creek stock near the showings are black argillite of the Active formation containing one or more bands of light- and dark-grey limestone and limy argillite a few tens of feet thick. The calcareous rocks are locally altered to skarn which contains scheelite. In addition to pyrite, the quartz veins contain minor amounts of galena, sphalerite, and molybdenite.

The gold quartz veins are described in Annual Reports for 1918 (p. 172) and 1932 (p. 195). Tungsten mineralization is described by Hedley (*B.C. Dept. of Mines,* Bull. 10 Rev., p. 148) as follows:—

"The principal working is an adit driven 85 feet northwesterly in granite to a contact with argillite. A northern branch of the adit also reaches argillite and a second branch, the face of which is 110 feet north of the portal, encounters a quartz vein as much as 5 feet wide, which follows a granite-skarn contact. The skarn is exposed on the west side of the vein for a distance of 20 feet and is of unknown width. Disseminated scheelite occurs in the skarn for a vertical distance of nearly 20 feet, as seen in a shallow winze at the face of the drift; the skarn contains much watery quartz and some sulphides, principally pyrite. The grade of this material, as exposed, was estimated to be a little more than 0.5 per cent tungstic oxide.

"Some open-cuts have been put in on the contact at intervals, from 100 feet south of the adit to 750 feet north. A band of limestone, as much as 15 feet thick, follows the contact and dips away from it beneath argillites. Skarn is developed locally in this limestone and contains small amounts of scheelite. At the northernmost end of the open-cuts, float containing worthwhile scheelite was discovered just before snow fell. Other old workings extend along this contact, but were not seen at the time of examination in late October, 1942."

[References: *Minister of Mines, B.C.,* Ann. Repts., 1918, p. 172; 1932, p. 195; *B.C. Dept. of Mines,* Bull. 10 Rev., 1943, p. 148; Walker, 1934, p. 85.]

Last Chance

The Last Chance group of claims is held by record by New Jersey Zinc Exploration Company (Canada) Ltd., company office, 525 Seymour Street, Vancouver. The claims are along the Last Chance Valley at the head of Dunlop Creek about 3½ miles east of Ymir. They were located about 1949 by E. P. Haukedahl and associates, of Ymir. The claims cover a fault zone, the northern extension of the Oxide fault (*see* p. 133), which follows the east side of the valley. The fault strikes north 30 degrees east, dips steeply to the east, and separates black argillite of the Active formation on the east from quartzites resembling those of the Navada member of the Quartzite Range formation on the west. Foliation in all the rocks dips to the east.

Exploration has been for lead-zinc mineralization along the fault. The Last Chance Valley, at an elevation of about 5,000 feet, slopes gently to the south and contains three small marshy ponds. Outcrops are scarce, and exploratory work has been directed toward testing the fault zone close to the ponds. Six short adits have been driven immediately east of the lowest pond, and bulldozer cuts mainly on the east side of the valley have been made from about 1,500 feet south of the lowest pond as far north as the highest pond, a total distance of nearly 5,000 feet. Soils have been tested geochemically at places along the valley (*see* Livingston, 1953). Zinc mineralization, locally highly oxidized, was found in two of the adits in dolomite in the Active formation. The bulldozer cuts were mainly in slumped and broken-up black argillite. Two short drill-holes have been made, one about 450 feet southeast of the south end of the lowest lake and the second about 2,000 feet south 20 degrees west from the lake. The second hole was collared in quartzite and drilled eastward through the fault into the Active formation. It encountered dolomite in the Active formation but no significant mineralization.

[References: *Minister of Mines, B.C.*, Ann. Rept., 1950, p. 121; Livingston, 1953.]

Lomond This property, also known as International Lead and Iron, comprises fifteen Crown-granted claims lying between the Reeves MacDonald property and the International Boundary on the east side of the Pend d'Oreille River. The claims are owned by International Lead and Zinc Mines Ltd., c/o 789 West Pender Street, Vancouver.

A camp consisting of several frame buildings is on the Nelway–Waneta road about 2 miles west of Nelway. The main showings, on Lomond Creek, are reached by a road three-tenths of a mile long that leaves the main road about half a mile west of the camp. Showings on the hill north of the camp are near a road that leaves the main road about half a mile east of the camp. A third showing on the east bank of the Pend d'Oreille River 400 feet north of the International Boundary is reached by a logging-road that leaves the main road about a mile west of the camp.

Mineralization at the three showings consists of seams and pods of earthy brown limonite containing layers of hard brown limonite in dolomite of the middle member of the Nelway formation. Nodules of galena and cerussite have been found within the limonite on Lomond Creek. No large body of sulphides has been discovered.

The property is first mentioned in the Annual Report for 1908, when it was being prospected by H. H. Shallenberger, of Spokane, who Crown-granted the claims in 1913. They were purchased by the present owners from Mrs. H. H. Shallenberger in 1951. In 1946 and 1947 Sheep Creek Gold Mines Limited held the claims under option and did 816 feet of diamond drilling in a search for sulphide mineralization. The results of the drilling are reported to have been disappointing. The present owners made a geological study of the claims in 1952 and did some bulldozer stripping but have since done no work on the property.

Shipments of 7,292 tons of iron oxide were made from the property by lessees in 1948, 1949, and 1950. This material was trucked to the Lehigh Cement Company at Metalline Falls, Washington, for use in the manufacture of cement. In the same period 19 tons of lead ore containing 38 ounces of silver, 9,702 pounds of lead, and 962 pounds of zinc was shipped to the Trail smelter.

The largest limonite deposits are those on Lomond Creek south and west of the camp (*see* Fig. 13). Due south of the camp, on the steep south bank of Lomond Creek, lenses of limonite have been exposed by stripping for a distance of about 300 feet along the creek. Exposures of limonite extend from creek level to as high as 40 feet above the creek. Several short adits driven into the limonite are now caved. The most easterly part of the stripping exposes two limonite layers 12 and 5 feet wide separated by about 10 feet of crumbly dolomite. These layers can be followed for about 25 feet to the west, beyond which they are obscured by slumping. The limonite layers are approximately parallel to banding in the dolomite that strikes east and dips south at about 30 degrees. Some of the limonite does, however, cut across banding of the dolomite at steep angles and at places appears to follow irregular fractures in the dolomite.

No limonite is seen in the dolomite exposed for 400 feet to the southwest along Lomond Creek, beyond which point limonite has been mined from a large pit on the north side of the creek. Several seams of limonite are seen approximately parallel to banding of the dolomite. The thickest seam exposed near the west end of the pit is 10 feet thick. An old adit driven 73 feet northwestward beneath the pit is still accessible. It encounters no limonite, and a 60-degree raise from the north end of the adit encountered only one small irregular pod of limonite in highly fractured dolomite.

Nodules of galena and cerussite are reported to occur in the limonite but were not seen in place by the writers. A few specimens piled near the most easterly pit were examined, but it is not known whether they are representative. Some are composed of coarse-grained galena coated with finely crystalline cerussite; others are mainly hard black botryoidal limonite upon which are clear slender crystals of cerussite.

Four samples were taken at the Lomond Creek showings, and their locations are shown in Figure 13. Sample No. 1, across 5 feet, included 3 feet of soft red limonite, 6 inches of weathered dolomite, and 2½ feet of soft limonite containing nodules of hard limonite. Sample No. 1 assayed: Silver, *nil;* lead, 1.20 per cent; zinc, 1.6 per cent. Sample No. 2, across a 12-foot band of soft limonite with some hard limonite nodules, assayed: Silver, *nil;* lead, 1.04 per cent; zinc, 1.7 per cent. Sample No. 3, taken at the portal of an old caved adit across a 2½-foot limonite band containing layers of an unidentified white mineral, assayed: Silver, 0.1 oz. per ton; lead, 9.62 per cent; zinc, 2.6 per cent. Sample No. 4, in the large pit, was taken across 5 feet of soft limonite containing some hard limonite. It assayed: Silver, 0.3 oz. per ton; lead, 1.20 per cent; zinc, 2.7 per cent.

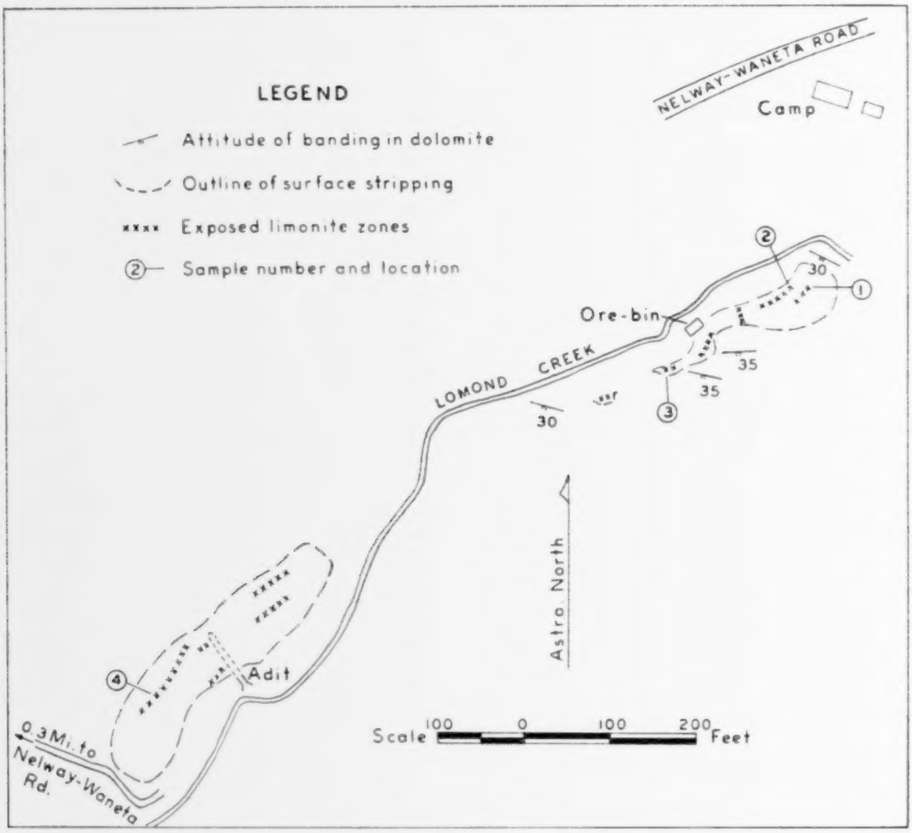
LEGEND
Attitude of banding in dolomite
Outline of surface stripping
Exposed limonite zones
② Sample number and location
NELWAY-WANETA ROAD
Camp
②
30
①
Ore-bin
LOMOND CREEK
35
35
30
③
Astro North
④
Adit
0.3 Mi. to Nelway-Waneta Rd.
Scale 100 0 100 200 Feet

Figure 13. Map of the main showings, Lomond property.

The limonite showing on the east bank of the river is similar in occurrence to the showings on Lomond Creek. The limonite is in both soft and hard botryoidal and stalactitic masses. The showing consists of a shallow bulldozer stripping on a bench about 35 feet above river level. Limonite is exposed over an area of about 30 by 40 feet; the attitude of the zone and its relation to the surrounding dolomite is obscure. The adit described by Walker (1934, p. 62) in this locality could not be found and is probably covered by debris from the bulldozer stripping.

On the hillside north of the Lomond Creek showings there are several occurrences of limonite in dolomite in which banding strikes east and dips 30 to 40 degrees to the south. The dolomite is locally highly fractured and brecciated, but the limonite zones are not obviously related to the fracturing in most cases. The most westerly showing on the hill is above the road at 2,800 feet elevation (*see* Fig. 3). It is explored by some old trenches and by a bulldozer stripping exposing 5 feet of limonite for a length of 30 feet. A sample across 5 feet of limonite, including both hard and soft varieties, assayed: Silver, 0.1 oz. per ton; lead, 1.01 per cent; zinc, 0.57 per cent. At 3,200 feet elevation, about 2,000 feet east of the last-mentioned showing, is an area in which several small pits have been dug into limonite zones in dolomite. The limonite here is mostly in steeply dipping fractures that cut across the banding of the dolomite. A sample across 3 feet of hard limonite, which is the widest zone in this area, assayed: Silver, 0.8 oz. per ton; lead, 0.70 per cent; zinc, 1.6 per cent.

The limonite deposits on the Lomond property have been generally considered to represent completely oxidized bodies of iron sulphides that contained some galena and sphalerite. No remnants of iron sulphides have been found, however, and no limonite " boxworks " occur that might provide a clue to the origin of the iron. Hard botryoidal limonite and stalactitic forms are found at all the showings and are evidence of transportation and redeposition.

[References: *Minister of Mines, B.C.,* Ann. Rept., 1948, pp. 136, 195; Walker, 1934, p. 62.]

Lone Silver

The Lone Silver property consists of three claims held by record by John and Robert Sapples, of Salmo. The claims, known as the Lone Silver No. 1, Lone Silver No. 2, and Lone Silver No. 3, are east of Rosebud Lake. The workings are about half a mile east of the lake near the bottom of the slope forming the southeast side of the valley in which the lake lies.

The property, originally known as the Hope, shipped silver-lead ore in 1909, 1910, 1914, and 1915, totalling 86 tons and containing: Gold, 22 oz.; silver, 13,461 oz.; lead, 12,051 lb. The claims lapsed and the property lay idle until 1935, when it was located by the present owners. Shipments of ore in 1936, 1937, 1938, 1940, and 1941 totalled 106 tons, with a gross content of gold, 64 oz.; silver, 8,850 oz.; lead, 11,639 lb.; zinc, 8,141 lb.

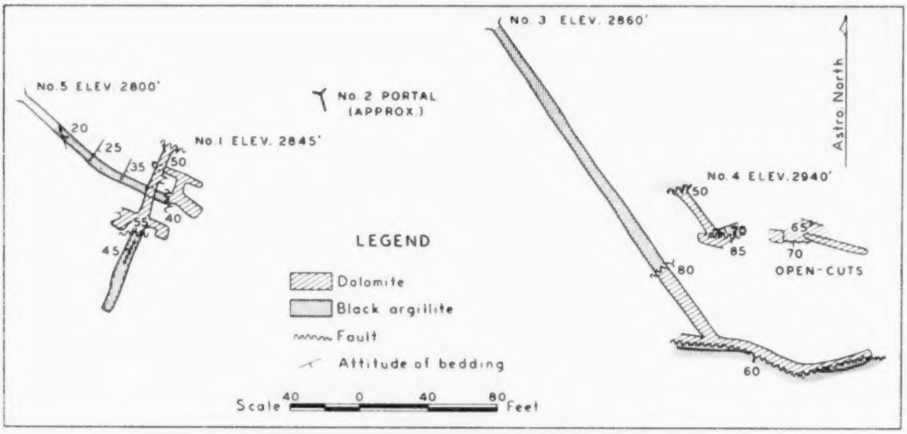

Figure 14. Map of the main workings, Lone Silver mine.

The main workings are shown in Figure 14. Adits No. 1 to No. 4 are referred to in the 1936 Annual Report (pp. E 16–E 18). These adits and open cuts to the east of them were made between 1909 and 1915. Mining in 1936 was done in No. 1 adit, and subsequently another adit, No. 5, was driven below and west of No. 1. In 1952, when the property was visited, No. 5 and No. 4 adits were open, No. 1 and No. 3 were partly caved at the portals and underground, and No. 2 was completely caved at the portal.

Outcrops are scarce near the workings, but are fairly numerous to the southeast. They are of fine-grained grey dolomite of the middle member of the Nelway formation. Underground the dolomite is commonly a breccia made up of small angular fragments of dolomite surrounded by veinlets of white dolomite and quartz. Black argillite of the Active formation forms one or two rubbly outcrops near the workings and is found underground. It is mainly carbonaceous, locally limy argillite, and at places contains beds of argillaceous limestone. Soft graphitic schist marks zones of intense shearing in the argillite.

The dolomite is on the western overturned limb of a large anticline plunging at low angles to the southwest (*see* Fig. 3). The anticline is truncated at a small angle by the Black Bluff fault (*see* p. 58) which brings the dolomite into contact with the Active formation. Regionally the fault strikes northeastward and dips to the southeast. In the Lone Silver workings the Black Bluff fault is a zone of faults with a wide variety of attitudes. The faults are marked by zones of breccia in the dolomite and by graphitic schist in the argillite. The principal faults are shown in Figure 14. Few can be projected from one working to another, and it is probable that they change in attitude and are intersected by other faults.

Sample No.	Gold	Silver	Copper	Lead	Zinc	Description
	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent	Per Cent	
1	Trace	16.0	0.3	Trace	0.5	Face of drift, No. 4 level; 5-inch quartz vein with copper stain along hangingwall.
2	Trace	1.0	*Nil*	*Nil*	*Nil*	Face of drift, No. 4 level; 5 feet of brecciated limestone in footwall of No. 1.
3	Trace	2.4	*Nil*	*Nil*	*Nil*	Roof of drift at collar; 4.5 feet of brecciated limestone excluding 8 inches of quartz at hangingwall.
4	0.01	71.0	8.3	7.0	9.5	3 inches of sheared limestone showing copper stain.
5	0.12	5.0	0.1	*Nil*	3.0	14 inches of shattered limestone below No. 4.
6	0.90	33.5	1.2	3.0	3.0	9 inches of quartz with galena and copper stain lying on 2 inches of gouge below No. 5.
7	0.01	15.4	0.19	2.77	4.7	No. 5 adit, 4-inch quartz vein near west end of small stope.
8	*Nil*	*Nil*	*Nil*	0.19	*Nil*	No. 5 adit, across 5 feet of brecciated dolomite including quartz veinlets at east end of small stope.
9	0.04	16.8	0.24	1.79	2.1	Portal of No. 1 adit, sorted quartz-sulphide ore on dump.

Sulphides occur in dolomite, either in lenses of quartz or along fractures in dolomite breccia. Quartz veins contain fine-grained galena, pyrite, and tetrahedrite. The vein in No. 5 adit strikes north 70 degrees west, dips steeply, and is as much as 6 inches wide. The quartz pinches and swells irregularly and contains scattered sulphides. Sulphides are scarce in the dolomite breccia in No. 1 and No. 3 adits, but copper stain from weathering of tetrahedrite is fairly common. Relatively large quantities of dolomite have been stoped in these adits. Assays of samples taken by the writers, and others from the 1936 Annual Report are given in the table above. Samples 4, 5, and 6 were taken in a small stope in No. 1 adit, 10 feet west of the working, about 30 feet from the portal. Samples of brecciated dolomite taken at random across widths of several feet, in this stope and another on the east side of the adit, contained no gold or silver and only traces of copper, lead, and zinc.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1936, pp. E 16–E 18.]

Meadow View

The Meadow View group of six claims is held by record by B. and M. Feeney, of Salmo. The claims are on the east side of the Salmo Valley immediately north of the South Salmo River and cover Reeves limestone on the overturned limb of the Jersey anticline (*see* p. 68). The main showings are at the base of bluffs of limestone about a mile north of the South Salmo River near the overturned contact of the limestone and the Emerald argillite (*see* Fig. 3). The property was originally known as the Mortgage Lifter, and the Annual Report for 1926 refers to " irregular disseminations of grey copper, pyrite, occasional native silver, and in places molybdenite." Assays between 27 and 69 ounces per ton of silver and less than 1 per cent copper are reported. In 1952 the claims were optioned by Canadian Exploration Limited, and one hole was drilled from the top of the ridge east of the showings. The summary log of the hole (DH No. 14) is given in the Appendix. No significant mineralization was encountered.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1926, p. 281.]

Molly

The Molly group of ten Crown-granted claims, owned by The Consolidated Mining and Smelting Company of Canada, Limited, company office, Trail, is on the south side of Lost Creek about 4 miles east of the Nelson–Nelway highway. The property was originally located for molybdenite, and a small shipment was made during World War I. Scheelite was discovered in 1942 by Joe Gallo, of Howser, and a considerable amount of surface exploration for scheelite was done by the company that year. Molybdenum and tungsten mineralization are found along the southwest contact of the Lost Creek stock. Molybdenite occurs mainly in granitic rocks close to the contact, and scheelite is found in black argillites and limy argillites of the Active formation that have been altered to skarn. Molybdenite mineralization is described by Walker (1934) as follows:—

" The granite is jointed or sheeted more or less parallel to the contact with the sediments. The molybdenite occurs in the granite close to the contact and mostly in a sheeted zone having a maximum observed width of 10 feet. The sheeted zone strikes from 15 degrees to 25 degrees, and dips from 40 degrees westerly to vertical. The best mineralization appears to be at a point where the contact dips at low angles as if this point were near the top of the granite body. The northerly extension of the best mineralization appears to have been eroded away. A little molybdenite can be seen disseminated throughout the granite in the single, short adit."

Details of workings and molybdenite occurrences are given by Stevenson (1940).

Tungsten mineralization is described by Hedley (1943):—

" Mineralization is in skarn within light grey limestone adjacent to the granite and in a slight embayment in the contact. Sharply defined areas in the limestone are altered to skarn which contains abundant garnet. Sulphide minerals include pyrrhotite, pyrite, chalcopyrite, molybdenite, and rarely sphalerite.

" Scheelite occurs as small, disseminated grains in skarn and none is found in limestone. It is associated generally but not exclusively with sulphide minerals. Sulphides are most abundant in the main showing at the granite contact, but the scheelite content is lower at the contact than it is at a distance of 30 feet or more from it. At several points a better than average grade of scheelite was observed associated with relatively massive garnet.

" The main or easternmost showing has been completely stripped for a strike length of 200 feet and a width of 20 to 40 feet along a northwesterly trending contact. Limestone beds dip flatly south, at an average angle of about 15 degrees, and are displaced by one or two minor faults. Small areas of granite are discernible on the stripped area, suggesting that the upper surface of the granite is here highly irregular. Skarn is developed as two bedded replacement bodies, one of which is 3½ to a local maximum of 10 feet thick, is 80 feet long, and is seen to extend down the dip for about 20 feet. This skarn band extends from the main granite on the east to, apparently, a small granite mass on the west, although the alteration may cease short of this granite. The second skarn band is about 10 feet stratigraphically above the first and outcrops 15 feet to the south; the two bands barely overlap in plan. The second body of skarn is 50 feet long, 6 to 8 feet thick, and extends about 15 feet down the dip; farther down the dip it is, at least locally, succeeded by limestone. Fifteen feet farther west, past a small aplite dyke, the stripping is in argillaceous rocks.

" The grade of mineralization was estimated only. A maximum grade of possibly 2.0 per cent tungstic oxide was only locally seen. A tungstic oxide content of 0.5 per cent or somewhat less seems to be a fair estimate over the widths and lengths indicated.

" Northwest of this showing, along the trail, at distances of 80 and 200 feet, are two local occurrences of skarn in limestone. These are lenticular and are close to the granite contact.

"An additional 130 feet still farther to the northwest an old open-cut discloses skarn of a slightly different manner of occurrence. The open-cut at the time of examination was not cleaned out, but the southern face showed a mass of skarn 10 feet or more high and 6 to 10 feet wide, developed diagonally across the bedding of the limestone; two small masses of skarn were seen on the west wall of the open-cut. A few vaguely defined slips could be seen, and these might have served to introduce or to control the formation of the skarn, or else it formed along the axis of a roll in the structure. Mineralization here is somewhat stronger than the average of that in the main showing."

[References: *B.C. Dept. of Mines,* Bull. 9, 1940, pp. 54–57; Bull. 10 Rev., pp. 146–148; Walker, 1934, p. 85.]

Oxide

The Oxide group of recorded claims covers the ridge between Porcupine and Oscar Creeks about 4 miles east of Ymir. The claims are owned by New Jersey Zinc Exploration Company (Canada) Ltd., company office, 525 Seymour Street, Vancouver. The Jack Pot group lies to the south and the Last Chance group to the north.

The Oxide property is reached from the Porcupine Creek road by following a road that crosses Porcupine Creek about half a mile west of the Active Creek bridge (*see* Fig. 3). The road crosses the ridge between Porcupine and Oscar Creeks by way of the Oxide pass at an elevation of about 5,000 feet. The main showings are near the top on both sides of the ridge a short distance west of the pass. The workings consist of two long adits and several short ones, about a dozen open cuts, and about ten drill-holes. One of the long adits, Ox No. 4, is east of the road at an elevation of about 3,950 feet. The other, called the International adit, is west of the road at an elevation of about 4,450 feet.

A zone of limonite constituting the main showing on the property was discovered in 1943 by E. P. Haukedahl, of Ymir. Several trenches on the showing were made by Mr. Haukedahl, and in 1944 two holes were drilled by Leta Explorations Limited. From 1945 to 1947 the property was under option to International Mining Corporation (Canada) Limited. This company built the road from Porcupine Creek, erected a camp at an elevation of about 4,300 feet, below the International adit, and did some diamond drilling. In 1948 the property was optioned and subsequently purchased by the New Jersey Zinc company. Since 1948 considerable exploratory drilling has been done, and between 1950 and 1955 the Ox 4 adit was driven.

Rocks exposed on the property include white and micaceous quartzites resembling those of the Navada member of the Quartzite Range formation, black argillite of the Active formation, and grey limestone. Little is known of the stratigraphy, and correlation of the quartzites with the Navada member is based entirely on lithology. The limestone is probably part of the Active formation, though in many respects it is similar to the Reeves limestone (*see* pp. 33 and 37).

The mineralized zone follows a fault known as the Oxide fault (*see* McAllister, 1951, p. 38). The fault strikes about north 10 degrees east, dips steeply to the east, and separates quartzitic rocks on the west from black argillite and limestone on the east. The fault is of regional extent, and on the Oxide property is marked by a wide zone of crushed and sheared rock. It is exposed at a number of places in the workings and can be located for a strike distance of about 1,500 feet on the property. On the Oscar Creek slope it appears to be offset by a right-hand fault striking about north 70 degrees east. The Oxide fault occupies the same structural position between the Black Argillite and Mine Belts as the Argillite fault, but the two are not regarded as the same fault. The wide zone of crushed rock along the Oxide fault contrasts with the tight, bedded nature of the Argillite fault zone (*see* p. 57) and suggests that the Oxide fault zone has not been healed by metamorphism. The Oxide fault is probably a late fault which may have displaced the Argillite fault.

Very little is known of the structure near the Oxide fault. Several hundred feet east of the fault and southeast of the Oxide pass an asymmetric anticline plunging to the south has been recognized (*see* p. 74). Quartzite at the core of the anticline is succeeded upward by limestone, and the limestone in turn by black argillite. If the quartzite belongs to the Navada member and the limestone to the Active formation, the quartzite and limestone are separated by a bedding fault. Quartzites west of the Oxide fault dip steeply and uniformly to the east. Strong shearing and discontinuity of many of the white beds suggest that the quartzite sequence is isoclinally folded or is cut by bedding faults.

The mineralized zone consists of soft earthy limonite containing secondary lead and zinc minerals and rare nodules of galena. The secondary zinc minerals are reported to be hemimorphite ($H_2Zn_2SiO_5$) and parahopeite ($Zn_3P_2O_8.2H_2O$), and the principal secondary lead mineral is pyromorphite ($((PbCl)Pb_4(PO_4)_3)$). Manganese oxides are present locally.

The mineralized zone at several places is about 30 feet wide but at places on surface appears to be somewhat wider. It is exposed intermittently for a strike length of 1,400 feet, and the lowest exposures on the south side of the ridge are about 600 feet below the ridge crest.

A short adit, now caved, driven in 1948 north of the Oxide pass at an elevation of about 5,100 feet cuts the oxide zone at an angle of about 30 degrees. Samples taken in the adit in 1948 assayed as follows:—

Location	Gold	Silver	Lead	Zinc
	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent
Portal to 13 feet (lagged)	—	—	—	—
13 to 25 feet	*Nil*	0.4	0.7	16.7
25 to 35 feet	0.01	0.1	1.4	15.7
35 to 45 feet	Trace	*Nil*	2.0	2.5
45 to 55 feet	*Nil*	*Nil*	3.0	2.9
55 to 65 feet	*Nil*	*Nil*	1.3	2.0

The International adit, which was not examined by the writers, has been described as follows (*Minister of Mines, B.C.*, Ann. Rept., 1947, p. 160):—

"An old adit 60 feet long, a little more than 600 feet lower than the summit, was extended northward late in 1946, and the zone was intersected early in 1947 about 120 feet from the portal. Drifting extended to a distance of 643 feet from the portal in an average direction of north 10 degrees east.

"From the point where first encountered, the oxidized zone was followed for 105 feet but, because of swelling ground, the end of the drift was abandoned and, from a point 155 feet from the portal, drifting was continued about 30 feet in the foot-wall (west). Three crosscuts were driven to investigate the zone—one at 135 feet from the portal, one at 400 feet from the portal, and one at the face, 643 feet from the portal.

" The zone is heavily oxidized and contains much mud. Before the end of the year, running of soft, wet ground had filled most of the openings in the zone. The zone is reported to be as much as 24 feet wide and to contain some lead and zinc (more zinc than lead) in the oxidized material.

" The crosscut at the face was extended west for 75 feet and a hole was drilled down at minus 54 degrees, a distance of 378 feet, to pass through the zone which appeared to be about 15 feet wide. Five feet of core consisted of pyritic quartz and is reported to have yielded a low gold assay."

The intersection of pyritic quartz in the drill-hole is almost 100 feet east of the position of the oxidized zone projected from surface through the zone in the International adit, and the mineralization is unlike any found elsewhere on the property.

Attempts to find the oxide zone south of the International adit have been unsuccessful. No outcrops have been found along strike from the oxide zone exposed near the International adit portal, and the topography for as much as 2,000 feet south of the portal is suggestive of gross slumping. The Ox 4 adit was made with great difficulty through running ground. It was driven 140 feet from the portal on a bearing of about north 25 degrees west, and thence due north for 730 feet. All but the inner 200 feet is in soft crushed and sheared rock saturated with water. The outer 140 feet went through mainly black argillite with minor buff micaceous quartzite. The inner part of the adit is mainly in buff to light-grey sheared micaceous quartzite. Near the face the quartzite contains thin limy beds. No significant lead-zinc mineralization was found, and exploratory drilling proposed by the company from the adit was not done.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1947, p. 160; 1948, p. 131; McAllister, 1951.]

Pete Creek Prospects

Old trenches and pits on the slope south of Pete Creek between elevations of 2,800 and 3,000 feet are covered by the Beaver, Beaver No. 3, Beaverdell, and Apex claims recorded by E. Arnot, of Nelson, in 1954 and 1955. No published account of the prospects has been found. One prospect 400 feet south of Pete Creek at 2,825 feet elevation consists of a lens of sphalerite and galena mineralization at a contact between banded limestone and granitized quartzite. The mineralization is exposed in one pit to a depth of 5 feet but does not appear to continue much beyond the limits of the pit. A chip sample across 5 feet of the best mineralization on the north wall of the pit assayed: Silver, 1.0 oz. per ton; lead, 3.48 per cent; zinc, 5.1 per cent. Trenches along the limestone-quartzite contact on either side of the pit do not appear to have encountered any mineralization. The limestone near the pit is medium to coarse grained and contains disseminated tremolite.

About 1,500 feet southwest of the prospect just described, heavy pyrrhotite mineralization occurs at a contact between Reeves limestone and granitized siliceous rocks. The contact strikes north 75 degrees east, and mineralization has been found along it for 75 feet. The best mineralization is exposed in an old shaft about 20 feet deep at the west end of the mineralized zone. The collar of the shaft is in coarsely crystalline grey limestone close to a contact with quartzitic rocks. The limestone is partly altered to a green silicate rock, and on the shaft dump there is some white dolomite.

Red Bird

The Red Bird property consists of sixteen Crown-granted mineral claims and fractions owned by Hecla Mining Company, of Wallace, Idaho. The claims are west of and adjoin those of the Reeves MacDonald mine. They are south of the Pend d'Oreille River and cover an area about a mile square lying north of the west fork of Russian Creek, and between one-half and 2 miles west of Russian Creek. The main showings are between elevations of 2,500 and 3,000 feet on the north slope of a small steep valley running eastward toward the Pend d'Oreille River. Although the valley is a prominent one and is referred to as the valley of Red Bird Creek, it contains no stream above an elevation of 2,000 feet throughout the summer. Prominent rock bluffs line the valley, but away from the bluffs outcrops are scarce and slopes are covered with a thick tangle of shrubs.

The showings are reached by following the old pack-trail from the south end of the Old Red Bridge on the Pend d'Oreille River southward a distance of about 1½ miles to the lower adit at an elevation of 2,550 feet. From the lower adit, trails run up the valley of Red Bird Creek and switch back to an elevation of about 2,900 feet on the south side of the creek. The trails were made about 1927, were brushed out about 1947, and in 1956 were passable.*

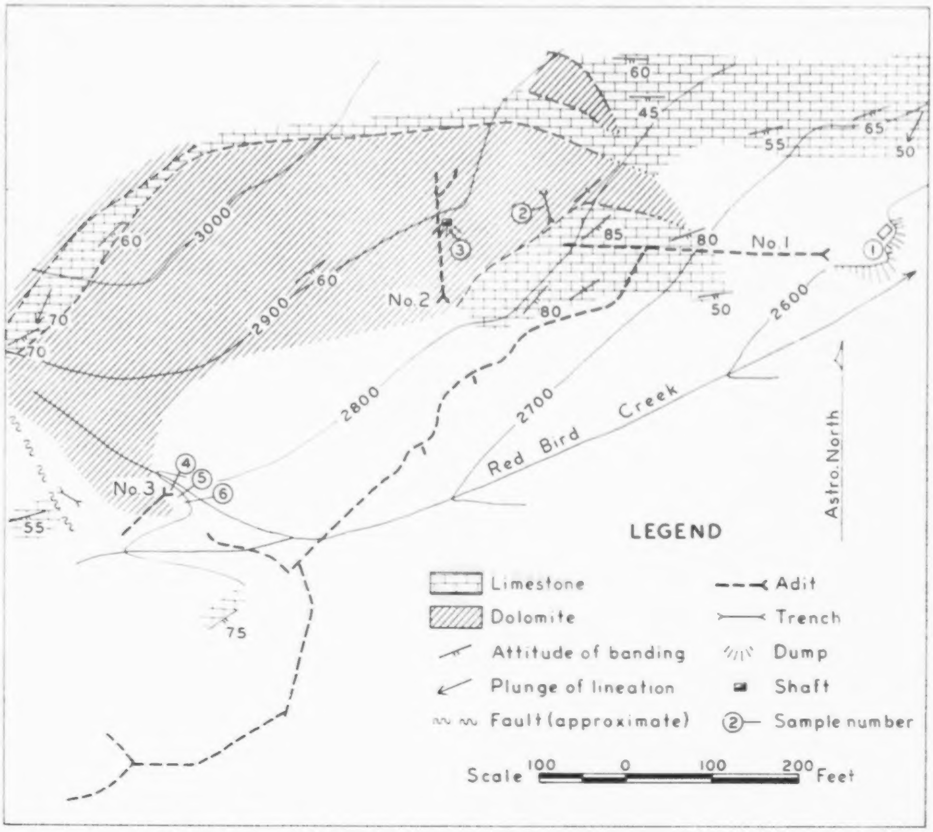
60
45
65
55
50
3000
60
②
③
85
80
No. 1
①
No. 2
60
2900
80
50
2600
70
70
2800
2700
Red Bird Creek
Astro. North
④
⑤
⑥
No. 3
55
75
LEGEND
Limestone
Dolomite
Attitude of banding
Plunge of lineation
Fault (approximate)
Adit
Trench
Dump
Shaft
Sample number
Scale 100 0 100 200 Feet

Figure 15. Geological map of the Red Bird property.

The early history of the Red Bird property is described by Walker (1934, p. 61) as follows:—

"The Red Bird group is first mentioned in the Annual Report of the B.C. Minister of Mines for 1924 when it was owned by S. Coulter and A. J. Campbell of Ymir. In 1925 it was reported to have been acquired by Conrad Wolfe and associates of Spokane, and in 1926 was acquired by the Red Bird Mining Company of Spokane. In 1927 the group comprised seventeen claims of about 800 acres extent. Up to this time about 1,000 feet of tunnelling had been done on the property. During 1928 the main adit was advanced to 1,200 feet, and some diamond drilling done. In 1929 the property was acquired by Boundary Basin Mines, Limited, who further drilled the property."

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* In 1957 and 1958 the road from the International Boundary to the west fork of Russian Creek (*see* Fig. 3) was extended to the Red Bird property. Extensive bulldozer strippings were made and a programme of diamond drilling was started.

As far as known, no work was done on the property between 1929 and 1944, when it was purchased by the Hecla company. In 1947 geological mapping and a small amount of surface work was done.

The main workings include three adits, a shaft, and several open cuts. All the underground workings were caved near the surface in the summer of 1955, and the open cuts were badly sloughed. Plans of the underground workings as well as geological and drill-hole data have been supplied by the Hecla company. The geology and topography shown in Figure 15 are the results of a compass and chain survey by the writers in August, 1955.

The showings are of secondary zinc and lead minerals in dolomitized zones in the Reeves limestone. The limestone dips southward and is underlain to the north by green and brown phyllite of the Truman member, which in turn is underlain by a sequence of quartzites belonging to the Reno and Quartzite Range formations in the core of the Salmo River anticline (*see* p. 64). The limestone is overlain to the south by black phyllite, probably belonging to the Emerald member. The limestone is blue-grey on weathered surfaces and shows black and white banding on fresh surfaces. It has a poor cleavage, along which are fine flakes of mica and locally wisps of black phyllite. Dolomite on the Red Bird property is light grey on fresh surfaces, but weathers buff. Both massive and textured types (*see* p. 86) are present, and irregular white quartz veinlets, some of which follow northwesterly striking joints, are common. The thickness of the dolomite is difficult to estimate because it lies nearly parallel to the slope of the hill. The east end of the dolomite zone above the No. 1 portal is covered by talus. The dolomite appears to widen westward up the hill from less than 100 feet to more than 150 feet. It is offset 900 to 1,000 feet west of No. 1 portal by a northerly trending fault and has not been positively identified west of the fault. North of this main zone of dolomite is a second mass of dolomite separated from the main one by a few tens of feet of limestone. It is poorly exposed but contains only minor rusty zones.

The showings are of soft earthy brown material locally containing hard nodules a few inches across which are brown and limonitic or whitish and contain recognizable secondary zinc and lead minerals. This rusty gossan is spread about the slopes, so that the extent and distribution of its source cannot be readily determined. None of the material sampled appeared to be in place. The location of samples is shown in Figure 15, and the assays are given in the following table:—

Sample No.	Width	Silver	Lead	Zinc
	Feet	Oz. per Ton	Per Cent	Per Cent
1	Grab	0.5	8.75	4.3
2	12	0.6	3.60	8.9
3	Grab	0.5	3.04	9.4
4	Grab	0.4	1.54	1.4
5	1	0.3	2.16	7.2
6	4	0.3	1.74	1.9

Samples No. 1 and No. 3 are of dump material. Nos. 2, 5, and 6 are of gossan fairly close to bedrock. No. 4 is of selected pieces of hard limonitic nodules occurring in the earthy material.

Maps supplied by Hecla Mining Company show a continuous mineralized zone in No. 1 adit about 600 feet long and ranging from 1 to 20 feet wide. This mineralized zone is parallel to the attitude of the rocks exposed on the surface and is terminated on the west by a fault. In this zone, grades as high as 30 per cent combined lead and zinc are reported, the grade of the zinc being generally much higher than that of the lead.

About 2,000 feet west and 500 feet south of the portal of No. 1 adit, at an elevation of about 3,300 feet on the east side of the bottom of Red Bird Creek valley, several small outcrops of dolomite are exposed. A short caved adit, known as No. 4, and a few trenches have been made. No sulphides or gossan were seen on the surface, but rusty nodules on a very small dump at the portal of the adit assayed: Silver, 0.1 oz. per ton; lead, 0.25 per cent; and zinc, 7.0 per cent. Outcrops are scarce at this locality, and although 30 to 50 feet of dolomite is exposed near the old workings, the true width and strike length of the dolomite are not known.

Strippings made in 1957 and 1958 expose gossan in dolomite at several places west of the area shown in Figure 15. The gossan occurs as irregular lenses similar in form to sulphide lenses at the other lead-zinc deposits in the Mine Belt, but no sulphides have been found. Because of the extensive cover in the valley of Red Bird Creek, continuity between the occurrences of gossan has not been established and the over-all shape of the mineralized zone is not apparent.

[Reference: Walker, 1934, p. 61.]

Red Rock (Michaely)

This property is on the north side of the Salmo River between McCormick Creek and Wallack Creek. It is controlled by Michaely Silver Lead Mines Ltd., a private company; L. A. Reid, secretary-treasurer, 1410 Bay Avenue, Trail. The workings are between elevations of 3,000 and 3,300 feet and are reached by about 1½ miles of road from the road along the north side of the Salmo River. In 1955 the road was not passable for vehicles much beyond the sawmill on the west side of McCormick Creek. The workings comprise Nos. 1, 2, and 3 adits that develop a lens of high-grade sulphide ore, and the "A" adit and several surface cuts that explore other mineralization near by. Buildings include a cabin and a frame structure.

The property was located in 1928 and has been held by the present company since 1932. The four adits and a number of trenches were completed prior to 1937, during which time 95 tons of ore was shipped. The property was idle until 1947, when 69 tons of ore was shipped. In 1948 a raise was driven in ore from No. 2 adit to surface and 208 tons of ore was shipped. A further shipment of 136 tons was made in 1949, to bring the total production to date to 508 tons containing: Gold, 5 oz.; silver, 4,781 oz.; lead, 180,748 lb.; and zinc, 196,440 lb. The collars of three diamond-drill holes can be seen near the face of No. 3 adit, but the result of this drilling is not known. No assessment work has been recorded on the claims recently, the owners having held the claims by relocating them.

Bedrock is very poorly exposed on much of the Red Rock property, but outcrops are fairly numerous close to the workings (*see* Fig. 16). An apparently conformable sequence of rocks striking about north 55 degrees east and dipping 65 degrees south includes quartzites of the Reno and Quartzite Range formations, Reeves limestone, and black phyllite that is in the upper part of the Laib formation and may be the Emerald member. The sequence is best displayed in No. 3 adit. At 35 feet from the portal, black phyllite of the Laib formation is underlain to the north by micaceous quartzite of the Lower Navada member of the Quartzite Range formation. This contact is a fault dipping 60 degrees southeast parallel to foliation in the adjacent rocks. There is only 20 feet of micaceous Lower Navada quartzite underlain by 25 feet of platy white Upper Navada quartzite that is in turn underlain by micaceous Reno quartzite. This appears to be a normal overturned sequence, though much thinner than is exposed on the east bank of McCormick Creek. Reeves limestone that underlies the Reno quartzite is only 35 feet thick and is bounded by bedding faults on both sides. There is no pronounced shearing on the south contact, but the absence of Truman and Upper Reno beds here indicates a structural break. The north contact of Reeves limestone with quartzitic rocks is marked by a strong shear on surface and in No. 2 adit but by only a weak shear in No. 3 adit. Outcrops of micaceous quartzite north of the limestone are tentatively correlated with the Reno formation and siliceous grey and black rocks with the Upper Laib formation. About 10 feet of grey limestone is exposed at the portal of "A" adit; it is not exposed elsewhere, except possibly in an old trench 100 feet to the southwest.

The structure at the Red Rock is dominated by bedding faults that have produced an apparently conformable sequence of beds of widely different stratigraphic position. Other faults and shears occur, particularly in rocks north of the main limestone. No folds have been recognized in the vicinity of the workings, but prominent linear structures in some of the quartzites plunge 40 degrees in a direction west of south and may represent the axis of obscure dragfolds.

Mineralization at the Red Rock includes the main lens of massive sulphide ore at the contact between Reeves limestone and the underlying quartzite, and some small showings in the quartzite, limestone, and argillite to the north. The main sulphide lens contains coarsely crystalline galena, sphalerite, and pyrite with manganiferous siderite and locally arsenopyrite. Mineralization appears to be a replacement of Reeves limestone adjacent to a highly sheared contact with micaceous quartzite. There is no dolomitization associated with this mineralization. A large surface stripping above No. 1 adit exposes some massive sulphides north and east of the portal, but the main sulphide body has been mined out to surface. The body on surface was reported (*Minister of Mines, B.C.*, Ann. Rept., 1936, p. E 29) to be composed of two parallel sulphide lenses totalling 5 or 6 feet wide for 45 feet and narrower for an additional 20 feet. At a point about 30 feet from the northeast end of the stripping, a spur of replacement mineralization extends south from the main lens to near the portal of No. 1 adit.

In No. 2 adit as much as 5 feet of massive sulphide mineralization was encountered at the sheared limestone-quartzite contact. Drifts to the northeast and southwest followed the lens of ore to where it appears to pinch out. There is much minor faulting in the ore in No. 2 adit, and it is possible that mineralization may have a greater strike length than the present working indicates. On surface, however, mineralization pinches out on both ends of the lens, and the limestone-quartzite contact as exposed along strike to the northeast for about 50 feet is barren. Thick overburden conceals this contact southwest from the present stripping. The relative positions of the ore on surface and in No. 2 adit as determined by compass survey indicate that it has a pronounced rake to the southwest. This rake is approximately parallel to the plunge of linear structures in the quartzite that are believed to represent the axes of dragfolds.

No. 3 adit appears to pass through the limestone band but reveals no mineralization at the limestone-quartzite contact. The contact in No. 3 adit is not strongly sheared as it is in No. 1 and No. 2 adits. The compass survey indicates that No. 3 adit may lie east of the projected position of the ore lens, but more accurate information on the rake of the ore is required. If the mineralization is controlled by the strong shear noted in No. 2 adit and on surface, this shear may steepen in dip and lie north of the face of No. 3 adit.

Other mineralization north of the main sulphide lens includes 3 feet of sulphides in grey limestone in a trench 60 feet north of the portal of No. 1 adit. A chip sample across 3 feet assayed: Silver, 0.3 oz. per ton; lead, 0.49 per cent; and zinc, 3.8 per cent. About 35 feet northeast of this trench a pit blasted into rock exposes a mineralized shear about 2 feet wide containing mainly galena. Galena is also reported in sheared black argillite near the face of "A" adit. No continuity has been shown for these showings.

[References: *Minister of Mines, B.C.*, Ann. Rept., 1936, p. E 28; Walker, 1934, p. 64.]

Reeves MacDonald

The Reeves MacDonald mine is on the Nelway–Waneta road 4 miles west of Nelway. The property comprises sixty-four Crown-granted mineral claims and fractions mostly within an area immediately south of the Salmo River and east of the Pend d'Oreille River (*see* Fig. 3). The mine is owned and operated by Reeves MacDonald Mines Limited; company office, 413 Granville Street, Vancouver; mine office, Remac.

The orebodies at the Reeves MacDonald mine are known as the Point, MacDonald, Reeves, B.L., O'Donnell, and Prospect orebodies. All production before 1953, when the mine closed, came from the Reeves orebody. When the mine was reopened in 1955, ore was also mined from the O'Donnell orebody. Underground workings consist of a main haulage adit level known as the River Tunnel or 1900* level, an upper adit level known as the Reeves or 2650 level (*see* Fig. 17), and fourteen interior levels at 50-foot intervals between the 1900 and 2650 levels close to the Reeves orebody. An inclined shaft in the footwall of the ore connects all levels. Ore above the 2650 level was mined by open-pit and glory-hole methods. Ore below the 1900 level is developed from an inclined shaft from this level. Other underground workings include the MacDonald, O'Donnell, and Prospect adits, all of which are old exploratory workings. The portal of the MacDonald adit, now caved, is 400 feet west of the portal of the River Tunnel. The O'Donnell adit, at 2,360 feet elevation, is about 2,700 feet northeast of the 2650 level portal. It was connected by raise with the 1900 level in 1956. The Prospect adits, at elevation 2,835 and 2,935 feet, are 1,600 feet east of the O'Donnell adit. Many surface trenches continue for about 800 feet east of the adits to an old shaft. The B.L. and Point orebodies have been stripped by bulldozer, the latter zone in preparation for surface mining. A pit about 500 feet southwest of the O'Donnell adit exposes mineralization referred to as the Norcross showing, which appears to be a westward extension of the O'Donnell orebody.

Some of the claims that now comprise the Reeves MacDonald property were located between 1910 and 1912 by James Quayle and J. H. (Black Jack) MacDonald, of Rossland. They held claims near the Pend d'Oreille River covering the Point and MacDonald orebodies. At about the same time or slightly later R. M. Reeves located claims covering the surface showings of the Reeves orebody. The first development work on the Reeves MacDonald was started in 1925 by the Victoria Syndicate, which acquired the property from Quayle, MacDonald, and Reeves. Work consisted of diamond drilling and driving the Reeves (2650 level) and MacDonald adits. By 1928 the Point, Reeves, MacDonald, O'Donnell, and Prospect orebodies had been explored, and in 1929 the B.L. and Norcross showings were found. The River Tunnel was driven in 1929 to a point where it intersected the Reeves orebody. In the same year, Pend Oreille Mines and Metals Company obtained control of the property. Operations were suspended in 1930, and, except for extending the River Tunnel in 1937, no work was done until 1947. In 1947 the mine was prepared for development, which began in March, 1948, with the driving of a raise from the 1900 to the 2650 level. Construction of the mill was also begun in 1948. Milling commenced in 1949, at the rate of 500 tons per day, and was increased to 1,000 tons per day in 1950. Production was maintained at this rate until April, 1953, and all milling ceased by July, 1953. Production between 1949 and 1953 totalled 1,057,804 tons of ore, which yielded concentrates containing 85,626 ounces of silver, 19,394,092 pounds of lead, 72,076,495 pounds of zinc, and 455,051 pounds of cadmium. The mine was reopened late in 1955, and since that time production has been maintained at an average rate of about 33,000 tons per month.

STRATIGRAPHY

The stratigraphic section of the rocks close to the mine is given in Table III. The section from Nugget quartzite to Reeves limestone was measured in the 1900 level west of the B.L. fault (*see* Fig. 18); the Reeves and Emerald members were measured along the Pend d'Oreille River north of the West fault.

The Nugget and Navada members of the Quartzite Range formation occupy the core of the Salmo River anticline (*see* p. 64). Bluffs of white quartzite of the Upper Nugget member are well exposed on the steep hillside north of the B.L. orebody and in the area east of the O'Donnell fault. Cleavage planes are normally several feet apart but are locally more closely spaced. Distinction between bedding and cleavage can be made only with difficulty. Steeply plunging fluted surfaces related to steeply plunging dragfolds are common. Only the upper beds of Nugget quartzite are exposed, and no estimate of the thickness of the member is possible.

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* The number of a level is its approximate elevation in feet above sea-level.

The Navada member of the Quartzite Range formation comprises blocky white quartzite, micaceous white, grey, and brown quartzite, greenish phyllite, and minor lenses of limestone. The contact between white Nugget quartzite and phyllitic Navada quartzite is sharp on the south limb of the Salmo River anticline but is difficult to place on the north limb, where isoclinal folding has produced complex interbanding of white and phyllitic quartzite. The Navada member is best exposed on the 1900 level west of the B.L. fault (*see* Fig. 18). The uppermost 35 feet of white quartzite grades downward into white, grey, and brown micaceous quartzite and green and brown phyllite totalling 285 feet thick. A zone of interbedded limestone and phyllite near the base of the Navada member is 20 feet thick on the 1900 level but has been thickened by dragfolding. On surface the limy zone is much thinner and locally contains only lenses of limestone a few inches thick. The upper white quartzite is a good marker which has been traced along the south limb of the Salmo River anticline but is missing at most places on the north limb.

The Reno formation is predominantly grey micaceous quartzite interbedded with dark-grey to black phyllite. The lower contact of the Reno formation with Upper Navada white quartzite is sharp and easily recognized. The uppermost 10 feet of formation is grey blocky quartzite which is locally calcareous and contains lenses of visible quartz grains. These grains average about 1 millimetre in diameter, with elongated grains as much as 4 millimetres long. Lenses of coarse grains in the Upper Reno are well displayed on the north limb of the Salmo River anticline, on the west bank of the Pend d'Oreille River, and due north of the Reeves glory-hole. Elsewhere the texture appears to have been destroyed by shearing, but the characteristic grey quartzite of the Upper Reno can be recognized. The Reno quartzite on the south limb of the Salmo River anticline is about 240 feet thick, but on the north limb it varies in thickness, and between the Point and West faults and locally east of the O'Donnell fault it is missing.

The Truman, Reeves, and Emerald members of the Laib formation are most readily seen in the underground workings and in diamond-drill cores. Surface exposures of the Truman and Emerald members are poor except along the Pend d'Oreille River and near the Reeves glory-hole.

Rocks mapped as the Truman member are made up of alternating bands of irregularly crenulated green schist, brown schist, and white and grey limestone. The true stratigraphic sequence is not known. The sequence, number, and thickness of schist and limestone units varies from place to place, apparently depending on the amount of folding; some of the brown schist may represent sheared Reno quartzite and in places the grey limestone may be part of the Reeves member. The Truman member in the footwall of the Reeves orebody is between 50 and 100 feet thick; along the Salmo River it has a maximum thickness of 50 feet and at places is entirely missing. Rocks along the northern side of the Argillite fault form a wide complex zone of interbedded limestone and are shown in Figure 17 as Truman member. The zone includes several bands of grey limestone, the most persistent being immediately north of the Argillite fault (*see* p. 128). The grey limestone, believed to be infolded Reeves limestone, is poorly banded and has a well-developed cleavage parallel to bedding. The schists and phyllites are various shades of green, brown, and grey. In the area south of the Prospect adits the sequence includes beds of grey micaceous quartzite which are thought to be infolds of Reno quartzite.

The Reeves member near the Reeves MacDonald mine is repeated three times by folding. It is found on both limbs of the Salmo River anticline and south of the anticline in what is known locally as the Prospect member. The Reeves member is mainly limestone and locally contains dolomite. Relatively small lenses of dolomite occur close to the Point, Reeves, B.L., and O'Donnell orebodies, and extensive masses of dolomite are found in the Prospect member. The limestone is a grey-weathering, grey, or black and white banded rock (*see* Plate XIII). It is finely crystalline and locally massive. Dark-grey or black bands are carbonaceous and contain very fine muscovite. Dolomite is finer grained than the limestone and is of two general types. Dolomite close to the orebodies is mottled or has a streaky banding known locally as " tweedy " texture. It commonly has a steeply plunging lineation. Dolomite in the Prospect member is mainly massive and light grey. Locally it is darker grey and poorly banded. Close to the Pend d'Oreille River and locally near the Prospect adits it is black and highly siliceous. Although most of the Prospect member is dolomite, in places, particularly west of the B.L. fault, it is grey limestone.

The Emerald member* is a crenulated black phyllite, somewhat graphitic and limy. In drill core black micaceous layers contain thin white limy lenses contorted by small dragfolds. The limy layers are mostly leached from surface outcrops.

The Active argillite, near the Argillite fault, is largely limy black argillite and dark-grey to black limestone. These rocks grade into non-limy black argillite, slate, and phyllite to the south.

Lamprophyre dykes of a wide variety have intruded all formations on the Reeves MacDonald property. They are mostly grey and black fine-grained dykes with phenocrysts of biotite. Some dykes which have been altered are pale green or grey. The dykes are commonly 1 to 5 feet wide but range from a few inches to 50 feet. A few of them contain inclusions of quartzite, granite, limestone, dolomite, and ore.

Many of the lamprophyres strike east and dip south parallel to formational contacts. Other dykes occur in or close to the four major transverse faults in the mine area. Sheared and altered dykes can be seen at the B.L. and O'Donnell faults on the 1900 level and at the Point and West faults on the banks of the Pend d'Oreille River at low water. A swarm of as many as five north-striking dykes cuts through the Reeves orebody and dips west approximately parallel to the rake of the orebody. Individual dykes average 2 feet wide but pinch and swell, and branch. The dykes cut the ore and in some places occupy small faults that offset the ore.

STRUCTURE

The most important structures in the Reeves MacDonald mine area are the Salmo River anticline, a steeply plunging syncline on the south limb of the anticline, bedding faults, and northerly trending transverse faults. The Salmo River anticline is a primary fold (*see* p. 47) of regional extent. The steeply plunging syncline, named the Reeves syncline, is a secondary fold that has controlled mineralization. The transverse faults have truncated the primary and secondary folds and the orebodies.

Transverse faults will be described first because they affect all the older structures. Four large faults—the O'Donnell, B.L., Point, and West faults—and several smaller ones are known. They strike northward and dip to the east, and are normal faults with a small strike-slip component of east side north. Displacement on the B.L. and O'Donnell faults has been calculated from the relative positions of the Reeves, B.L., and O'Donnell orebodies, which are faulted segments of a single mineralized zone. The orebodies plunge south 35 degrees west at 55 degrees.

The B.L. fault terminates the B.L. orebody on the west at about 2,300 feet elevation and presumably terminated the Reeves orebody on the east above the present surface. On the 1900 level the B.L. fault is a zone of sheared rock 4 feet wide striking north and dipping about 45 degrees east. The average strike between this point and the surface is north 5 to 10 degrees west. The average dip from the 1900 level to surface is 40 degrees. Displacement on the B.L. fault, calculated from the relative positions of the Reeves orebody and of the B.L. orebody as roughly outlined by surface diamond-drill holes, is 775 feet of normal dip slip and 275 feet of strike slip with east side north. Vertical displacement of the orebodies is about 500 feet.

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* This member is known as " the Garnet Schist " by mine geologists. Although garnets have been reported, the writers were unable to find any.

On the 1900 level 200 feet east of the B.L. fault a northerly striking fault zone dips 70 to 80 degrees east and causes a small offset in the same direction as the B.L. fault. This fault has not been recognized on surface.

About 800 feet west of the B.L. fault on the 1900 level a small transverse fault known as the Buller fault strikes north and dips 50 degrees east. Left-hand offset of the Reeves-Truman contact is less than 50 feet.

The O'Donnell fault* terminates the O'Donnell orebody on the west just below the 1900 level. On the 1900 level 6 inches of gouge occupies the most prominent fault plane, and as much as 5 feet of crushed dolomite lies east of it. This fault plane and subsidiary faults to the east strike between 10 and 20 degrees west of north and have an average dip of 45 degrees east. The average strike between the 1900 level and the fault at surface is difficult to calculate because the fault branches and changes strike abruptly below an elevation of 2,200 feet. The average dip from the surface to the 1900 level is 45 degrees east. From the relative positions of the B.L. and O'Donnell orebodies the fault movement is calculated to be 1,850 feet of normal dip slip, and 125 feet of strike slip with east side north. Vertical displacement of the orebody is 1,300 feet.

The Point fault, west of the Point orebody, is exposed on the north side of the Pend d'Oreille River at low water and has been located to the north in an area of sparse outcrop. It appears to strike about 10 degrees west of north and dip steeply east. Offsetting of beds and of the West fault along the Point fault indicates a movement similar to that on the B.L. and O'Donnell faults. By comparing cross-sections drawn on either side of the Point fault, it appears that the dip slip is about 1,000 feet and the strike slip about 500 feet, with east side north.

A small transverse fault 500 feet east of the Point fault, like the other faults, produces a left-hand offset. Offset of the Reeves, Truman, and Reno is about 200 feet. A small transverse fault cutting the southern band of Truman schist and limestone on the west side of the Pend d'Oreille River may be a continuation of this fault to the south.

The West fault, west of the Point fault on the Pend d'Oreille River, differs in strike from the other transverse faults but has the same left-hand offset. It strikes about north 35 degrees east at the river and dips 60 degrees southeast as determined from its surface trace. The West fault is offset along the Point fault a distance of about 500 feet. Its position on the east side of the Point fault has not been located precisely in the covered area southeast of the Salmo River.

The Salmo River anticline (*see* p. 64) is a regional overturned isoclinal fold. Near the mine the axial plane strikes north 70 to 80 degrees east and dips 50 to 60 degrees to the south. The axis probably plunges at a low angle to the west. Quartzite of the Nugget and Navada members forms the core of the anticline, and the Reno quartzite, Truman, Reeves, and Emerald members are repeated on the limbs. The rock units are not repeated symmetrically on either side of the axial plane because the anticline is complicated by bedding faults and secondary folds (*see* Fig. 4a).

Structures south of the Salmo River anticline and north of the Argillite fault are obscured by intense shearing. Foliation strikes north 70 to 80 degrees east and dips 50 to 60 degrees to the south. Repetition of the Reeves limestone in the Prospect section south of the Reeves MacDonald mine shows that the Salmo River anticline is followed to the south by a smaller isoclinal syncline with the Emerald member at the core. Between the Prospect dolomite and the Argillite fault the rocks are strongly sheared equivalents of mainly the Truman member, with possible Upper Reno quartzite near the middle and a number of bands of the Reeves limestone near the fault. The rock types suggest the structure is anticlinal.

Steeply plunging folds are superimposed on the Salmo River anticline. These secondary folds (*see* p. 47) range in size from small crenulations to folds with amplitudes measured in hundreds of feet. Typically they are Z-shaped and are not related to the primary folds. Many are sheared or truncated by bedding faults and the Z-shape is incomplete. One such fold is the Reeves syncline, which contains the Reeves, B.L., and O'Donnell orebodies.

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* In 1958 another transverse fault striking northward and dipping gently to the east was found about 600 feet east of the O'Donnell fault.

The Reeves syncline is on the south limb of the Salmo River anticline. It has been recognized only east of the Pend d'Oreille River, but probably continues west of the river in an area of poor outcrop. The syncline plunges southwest at about 55 degrees; the axial plane strikes between north 70 degrees east and east and dips 50 to 60 degrees to the south. The syncline has been recognized from relationships between the Reeves and Truman members and from folds exposed on the 1900 level. On surface the form of the syncline is obscured by the B.L. and O'Donnell faults. West of the B.L. fault the Truman member is repeated on either side of the Reeves limestone, and the limestone thins from about 650 feet near the townsite to about 200 feet near the B.L. fault. On the 1900 level (*see* Fig. 18) the syncline is more complete than on surface. West of the B.L. fault the Reeves limestone thins and tails out eastward into rocks of the Truman member in a series of highly attenuated small isoclinal folds. The folds cannot be seen, and interbanded limestone and phyllite form an apparently homoclinal sequence. East of the B.L. fault, highly attenuated small isoclinal folds near the trough of the Reeves syncline (*see* Plate XII) plunge 50 to 60 degrees to the southwest. Bands of limestone most commonly form synclines open to the west, and those of phyllite are generally anticlines open to the east. The Truman member is remarkably thickened, and the Reeves limestone highly infolded with it in the trough of the syncline.

The Truman member on the south limb of the Reeves syncline is in fault contact with the Emerald member to the south.

Three principal bedding or thrust faults have been recognized near the Reeves MacDonald mine. One of these is the Argillite fault between the Mine Belt and the Black Argillite Belt. It is described on page 56. Another bedding fault on the overturned limb of the Salmo River anticline has also been described (p. 65). The third fault along the south side of the Reeves syncline is exposed at several places on the 1900 level and has been intersected by drill-holes. The fault is followed by a lamprophyre dyke a few feet thick. Strongly sheared and crenulated black schist of the Emerald member lies to the south, and a narrow band of grey limestone associated with green and brown phyllite of the Truman member lies to the north. East of the O'Donnell fault the bedding fault probably continues beyond the Reeves and Truman members in the trough of the Reeves syncline. Farther east the bedding fault, though it is not exposed, probably brings the Emerald member into contact with quartzites of the Reno and Quartzite Range formations. The fault is not exposed west of the Pend d'Oreille River, but it probably strikes more nearly west than the regional strike of the formations and gradually truncates the Reeves syncline.

OREBODIES

The Point, MacDonald, Reeves, B.L., and O'Donnell orebodies are replacement deposits in the Reeves limestone on the south limb of the Salmo River anticline. The Prospect orebody is in the Prospect dolomite. The deposits consist of bands, lenses, and disseminated grains of pyrite, honey-coloured sphalerite, and galena, in dolomite. The Reeves, B.L., and O'Donnell orebodies are faulted segments of one zone.* The Point and MacDonald and Prospect are separate deposits. The size and shape of the Reeves orebody is well known above the 1900 level because it has been extensively mined. The B.L., O'Donnell, and Point orebodies are partly mined, and the MacDonald and Prospect zones are incompletely explored.

Generalized plans of the Reeves orebody on the 1900 and 2650 levels are shown in Figure 18. The orebody has the form of an attenuated syncline with limbs striking eastward and dipping 50 to 60 degrees to the south and axis plunging south 35 degrees west at about 55 degrees. In detail, outlines of the orebody are irregular, but the general synclinal shape persists from the 1900 level to the surface 900 feet above.* The main trough section of the Reeves orebody is about 350 feet long, and has been stoped at the widest part to widths of about 80 feet. The footwall or north limb of the orebody thins westward from the thick trough section, and on the 1970 level where mining has been most extensive it is 10 to 20 feet thick and about 500 feet long. The hangingwall limb of the Reeves orebody has been stoped for a few tens of feet west of the thick trough section. Sparse mineralization continues along the hangingwall limb for a few hundred feet west of the stoped area, but has not been continuous enough or high enough in grade to be mined.

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* In 1958 a fourth faulted segment of the same zone was found east of the O'Donnell orebody.

Much of the ore in the Reeves orebody has a more or less well-pronounced banding. Bands of sulphides, which range from a fraction of an inch to a few inches wide, are generally discontinuous and locally highly contorted. Seen together they show the orebody to have a uniform dip and plunge and a folded lenticular form in a plane perpendicular to the plunge. Folds within the orebody are irregular, but some of them can be recognized from one level to the next and appear to be persistent along the plunge. Some ore is a breccia composed of rounded and angular rotated fragments of dolomite, and locally of limestone, in massive sulphides. Breccias are commonly rich in pyrite and are more abundant on the limbs than in the trough section of the orebody. Banded ore is cut by veinlets of coarsely crystalline white calcite, dolomite, and quartz a fraction of an inch wide and a few inches long. They either crosscut the banding or are parallel to it. Minor amounts of sphalerite and galena are found in the veinlets. Details of the relationships between ore, dolomite, and limestone on the 2650 level are shown by Green (1954, Fig. 2).

The dolomite zone with which the Reeves orebody is associated has the same synclinal form as the orebody. The limbs dip 50 to 60 degrees to the south, and the axis plunges about 55 degrees to the southwest. Dolomite on the limbs lenses out into limestone to the west. On the south limb another lens of dolomite is found a few tens of feet along strike from the end of the dolomite containing the Reeves orebody (*see* Fig. 17). This western lens is known only on surface and in part on the 1900 level. The outline on surface suggests that it has the form of a syncline. No ore is known in this western lens of dolomite.

The Reeves orebody and associated dolomite zone are in the Reeves syncline. The orebody, the dolomite, and the syncline have similar form and attitude. The dolomite is more or less centrally located within the limestone. The orebody is well up in the dolomite syncline, close to the limestone wedge between the two dolomite limbs. It is apparent that dolomitization (*see* p. 86) has been controlled by the Reeves syncline and that sulphide mineralization has followed essentially the same structure in the dolomite.

The B.L. orebody has been exposed by surface strippings and partly explored by drilling. It is surrounded by dolomite and appears to have the same shape and plunge as the Reeves orebody. The eastern end of the B.L. orebody is truncated by the B.L. fault at about 2,300 feet elevation. Only limestone which tails out eastward into the Truman member is found on the 1900 level below the B.L. orebody (*see* Fig. 18).

The O'Donnell orebody is exposed in the O'Donnell adit (elevation, 2,370 feet) and on the 1900 level and is being mined between these levels. It is surrounded by dolomite and appears to have the same shape and plunge as the Reeves orebody, though the section of barren limestone between the dolomite halo and the Truman formation is thinner than it is to the west.

A detailed map of the Point orebody is given by W. H. White in the Annual Report for 1949 (p. 169). Disseminated sphalerite, galena, and pyrite occur in a dolomitized zone in Reeves limestone on the south limb of the Salmo River anticline. The dolomite zone is within 50 to 100 feet of rocks of the Truman member to the north; the southern edge of the dolomite lies beneath the Pend d'Oreille River. At low water, two mineralized zones in the dolomite are exposed, each about 20 feet thick and separated by 60 feet of barren dolomite. The Reeves limestone near the Point orebody is folded into an open, south-plunging syncline that is complex in detail. This folding may be related to movement on the Point fault and on a smaller transverse fault east of the Point orebody. Small Z-shaped dragfolds within the ore are of the type found in the Reeves orebody, and it is probable that the Point orebody plunges to the southwest parallel to these folds. A continuation of the Point orebody on the west side of the Point fault has not been located.

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* Exploration below the 1900 level indicates that the Reeves orebody continues at least to the 1100 and probably to the 500 level.

The portal of the MacDonald adit was caved in 1954 and 1955 when the property was being studied. The adit is reported to be driven in earthy, calcareous, and limonitic materials containing secondary lead and zinc minerals . The first 1,500 feet from the portal of the Reeves 1900 level is also in leached limestone with limonite zones that are considered to be part of the oxidized MacDonald orebody. In the Reeves 1900 level the mineralization is in dolomitized limestone, but the size and shape of the dolomitized zone is not known. It appears to be closer to the hangingwall than the footwall side of the band of Reeves limestone. Geological features of the bedrock surface are unknown because the surface in the vicinity of the MacDonald orebody is covered by alluvium.

The Prospect orebody is in the Prospect dolomite (*see* p. 141). Mineralization consists of coarse-grained pyrite, fine-grained light-brown sphalerite, and minor galena. Sulphide replacement is mainly parallel to a faint banding in fine-grained light-grey dolomite. Lenses of quartz also follow this banding. Where sulphides are abundant the grey dolomite is coarse grained, with crystals as much as one-half inch in diameter. Little is known about the size and shape of the Prospect orebody. It has been explored by two adits 300 and 130 feet long and by a number of surface cuts, none of which indicate a large body of ore. Unlike the other orebodies, which occur in a zone of local dolomitization, the Prospect orebody is in a zone of widespread dolomitization.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1949, p. 169; 1950, p. 129; 1951, p. 142; 1952, p. 153; 1953, p. 119; 1955, p. 53; 1956, p. 85; Walker, 1934, p. 57.]

Salmo Consolidated

Five Crown-granted claims and fractions on the east side of Hedgehog Creek, the former Salmo Consolidated property, reverted for taxes in 1956. One fractional claim is owned by Frances Bradley, of Chilliwack. The claims cover a number of sulphide-bearing quartz-carbonate veins in granitic rocks near the northwest edge of the Sheep Creek stock. Original workings on the showings, including a relatively deep shaft, date from the early years of the Sheep Creek camp. In 1926 the property was acquired by P. F. Horton and associates, of Nelson, who formed Salmo Consolidated Mines, Limited, in 1928. Three adits and several open cuts were made between 1926 and 1929, but no work has been done since. The main workings are between elevations of 5,000 and 5,300 feet near the end of a road running west from the road to the Reno mine. The showings are described by Walker (1934, p. 74) as follows:—

" The workings consist of the old shaft, some old surface cuts, three new adits, and some twenty new surface cuts. The upper and greater part of the 116-foot shaft has an easterly slope of 67 degrees; the lower part has a slope of 52 degrees. The vein has an average dip of 56 degrees to 58 degrees east. It is visible in the upper part of the shaft and in two crosscuts, one from the bottom of the shaft and one 20 feet up. It varies in width from 1 to 6 feet, and consists of a low-grade mineralization of sphalerite, galena, and pyrite in a quartz and calcite gangue.

" The road level adit is on a level with the collar of the shaft and 25 feet north of it. The adit follows the vein which just past the portal turns more easterly, the dip at the same place decreasing to 40 degrees and less. The vein pinches and swells, the best showing having a length of about 35 feet and a greatest width of 3 feet. The vein dies away in a length of 125 feet. Near the face of the adit a little galena and pyrite show above a joint in the granodiorite, and a little mineral can be seen in a crosscut close to the face. A crosscut to the south at 38 feet from the portal is barren.

" One hundred and fifty feet southerly, and 45 feet lower in elevation than the shaft, is a 75-foot adit, opening up a small vein that has been drifted on for 23 feet. This vein is a few inches wide and is composed of milky quartz with some galena, and pyrite. It dips 59 degrees east and is the downward continuation of a small showing on the edge of the road 85 feet south of the shaft. This narrow vein does not appear to be the one in which the shaft was sunk, but its trend is irregular and possibly the two veins are one and the same.

" The third adit has been driven from a point 275 feet westerly, and 160 feet lower in elevation than the road level adit. At 360 feet from the portal it intersects the vein at a point approximately 70 feet down the dip from the bottom of the shaft. The vein has been drifted on for 100 feet to the north and 150 feet to the south. As exposed in the north drift the vein is very irregular, really being lenses of vein matter in the granodiorite. The greatest width consists of 4 feet of quartz and calcite gangue holding fine-grained galena, sphalerite, and pyrite, and 2 feet of vein matter and granite, and belongs to a body about 50 feet long. A 30-foot raise shows the lens to pinch out 25 feet above the floor of the level. Another lens extending from the north drift into the south drift is about 60 feet long with a greatest width of 6 feet of vein matter and of granite with lenses of sulphides. To the south is another short lens of vein matter and granite joined to another lens which is crossed by a fracture that deflects to the east the southern part of the lens. From the fracture to the face of the drift, a distance of 35 feet, the vein averages 12 to 18 inches in width and is composed of quartz, pyrite, and galena.

" Of nineteen surface cuts just above the road level adit only two show mineralization, and this is small in amount. Higher up the hill, and east of these surface cuts, an old inclined working has been sunk on a quartz vein that is 1.3 feet wide, carries galena, and strikes 80 degrees with a 45-degree dip to the south. A small outcrop of a quartz vein lies 60 feet north of the last-mentioned showing and strikes 80 degrees with a very low dip south. A long surface cut to the north is barren. Easterly from this cut at the summit of the ridge is a small cut showing a narrow quartz vein in granodiorite. The vein strikes 70 degrees and dips south at a high angle. At the side of the cut there is a little pile of mineralized quartz similar to that at the old incline shaft, but none could be found in place. Some trenching has been done on the summit of the ridge but bedrock has not been exposed."

[References: *Minister of Mines, B.C.*, Ann. Repts., 1926, p. 280; 1928, p. 347; Walker, 1934, p. 73.]

Shenango Canyon

Showings of pyrite, sphalerite, and galena occur in Shenango Canyon on the Salmo River one-half to three-quarters of a mile west of the mouth of Creggan Creek. The showings are mainly on the south side of the river, but old workings, now scarcely recognizable, have been made on the north side. Showings on the south side of the river are reached by following an old trail from the Black Bluffs on the Nelson–Nelway highway to the canyon, a distance of about half a mile. A logging-road that crosses the Salmo River about half a mile north of the Black Bluffs passes the showings on the north side of the canyon.

" Mine tunnels " are shown on the Salmo map-sheet (*see* Walker, 1934) in Shenango Canyon, but the only published account of the property is in the Annual Report for 1929 (p. 355). The property was owned by M. C. Monaghan, of Nelson, and was optioned in 1929 and 1930 to The Consolidated Mining and Smelting Company of Canada, Limited. That company reports that in 1929 four holes were drilled totalling 1,246 feet, and that by July, 1930, six open cuts had been made. In 1948 and 1949 five claims known as the Rainbow group were located by I. C. Williams, of Salmo, and although the transaction was not recorded, it is understood that the claims were owned by Diem Mines Limited. In 1951 the claims were surveyed and optioned to Reeves MacDonald Mines Limited. Between September, 1951, and June, 1952, this company drilled three holes totalling about 2,600 feet. The option was dropped and the ground has been open for several years.

The workings include a short adit and several open cuts on the south side of the Salmo River, and an adit, now almost obscured by rubble, on the north side of the river just west of a line of continuous outcrop of limestone forming the canyon. The accompanying sketch-map (Fig. 19), made from a compass and chain survey in 1955, shows the outcrops, drill-holes, and main workings. The casing of hole No. 3 is exposed at low water near the edge of the Salmo River; it is one of four holes drilled by the Consolidated Mining and Smelting company. The other three holes could not be located. Holes Nos. 1 and 2 were drilled by Reeves MacDonald Mines Limited; the third hole drilled by this company is about 265 feet west and 180 feet south of No. 1 hole.

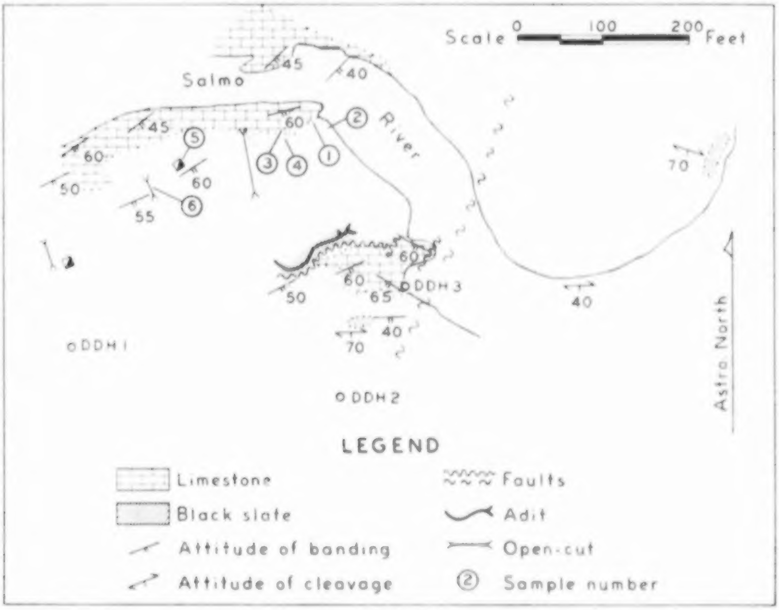

Figure 19. Geological map of the showings in Shenango Canyon.

The principal rock types near the showings are limestone and black slate. The limestone forms two bands striking east and dipping south. The southern band is grey, fine grained, and poorly banded and may belong either to the Reeves member or the lower part of the Nelway formation. It contains a few buff-weathering lenses, but no dolomite. The northern band, which is the Reeves limestone, forms the banks of the main part of Shenango Canyon. It is white, poorly banded, weathers grey, and locally contains siliceous lenses and bands of sulphides. The outcrops shown on Figure 19 are on the south side of a band of the Reeves limestone which, half a mile west of Shenango Canyon, is underlain to the north by the Truman member and by quartzites on the south limb of the Salmo River anticline.

The black slate is poorly exposed along the Salmo River and in the old adit on the south side of the river. North of drill-hole No. 2, rubbly outcrops are of blue-black limy slate. North of the river, highly contorted and locally limy slates probably belong to the

Active formation, but the correlation of highly sheared graphitic slate in the adit on the south side of the river is uncertain.

Because outcrops are scarce, little is known of the structure. The formations in general strike about north 70 degrees east, but strikes within the limestone vary from northeast to south 30 degrees east. Dips are mainly about 60 degrees to the south. A number of regional faults are close to the showings but cannot be recognized with certainty. The Black Bluff fault probably lies within a few hundred feet south of the showings. The Argillite fault or the Salmo Valley fault may lie on the south side of either band of limestone. Faults are exposed in the old adit on the south side of the river. The main fault in the adit strikes northeast and dips 45 to 50 degrees southeast. Two northeasterly striking, steeply dipping faults occur east of the adit and are probably subsidiary to a fault that lies farther east but is not exposed. This fault appears to truncate the two bands of limestone because they do not continue to the east.

Two types of mineralization—a sulphide-bearing quartz vein and disseminated sulphides in limestone—have been explored on the property. The quartz vein outcrops at the portal of the adit on the south side of the river and has been followed underground for about 80 feet. On surface it is as much as 3 feet thick, but underground it thins rapidly and for most of its length is less than 6 inches thick. It strikes northeast and dips 20 to 30 degrees southeast underground, but near the portal it is essentially horizontal. The vein is of white quartz containing small lenses of galena, sphalerite, and pyrite. Selected material from the dump at the portal of the adit assayed: Silver, 9.0 oz. per ton; lead, 10.0 per cent; and zinc, 6.2 per cent. A sample across the vein 2.5 feet wide a few feet from the portal inside the adit assayed: Silver, 1.3 oz. per ton; lead, 1.06 per cent; and zinc, 2.5 per cent.

The northern band of limestone on the south side of the river contains a zone of disseminated pyrite with small amounts of galena and sphalerite. The sulphide zone appears to be restricted to the south side of the limestone, and the bands of sulphides as well as the zone itself are parallel to the limestone. It is exposed over widths of 10 to 15 feet, but the total width of the mineralized zone appears to be as much as 50 feet. The zone is exposed at intervals for about 300 feet along strike on the south side of the river, and rubble of pyritic limestone at the portal of the old adit on the north side of the river indicates that it extends another 100 feet to the east. Possible extensions of the zone to the east and to the west are heavily drift-covered. Most of the limestone associated with sulphides is siliceous and contains lenses of white quartz parallel to the banding. The following table lists assays of samples of the sulphide zone; the sample locations are shown in Figure 19.

Sample No.	Width	Silver	Lead	Zinc
	Feet	Oz. per Ton	Per Cent	Per Cent
1	3	0.5	0.65	0.13
2	Grab	0.4	0.36	0.27
3	3.5	Trace	0.30	0.11
4	5.0	Trace	0.12	0.29
5	6.0	0.3	0.23	1.0
6	10.0	1.0	0.12	0.15

Spectrochemical analyses showed that all the samples contain a few per cent of barium, and barite has been identified in some of the samples.

Diamond-drill hole No. 3 was drilled northwest at minus 45 degrees, and the three holes drilled by the Reeves MacDonald company were inclined holes drilled north 30 degrees west. All the holes intersected the pyrite zone at depths between 150 and 300 feet below the surface. The width of the zone and the grades of lead and zinc were comparable to those found at the surface.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1929, p. 355.]

Silver Bell The Silver Bell Crown-granted claim, owned by J. G. McColeman, Stayner, Ontario, covers the top of a 6,700-foot hill about 3,000 feet northwest of the Reno mine. The main workings are at an elevation of 6,400 feet on the ridge running northwest from the hill. The showings are of sphalerite in grey crystalline dolomitized limestone in the Active formation near the southeast corner of the Hidden Creek stock. They are described by Walker (1934, p. 69) as follows:—

" The workings consist of a long stripping and an open-cut on the northeast side of the ridge, and smaller cuts just over the crest to the southwest. The long cut exposes a contact between granodiorite and limestone. This contact is on the southeast side of the large mass of granite east of Salmo whose marginal phase at this point is a rock of medium grain, low in quartz and varying from grey granodiorite to a light-coloured limestone almost free from ferromagnesian minerals. The long cut exposes limestone for 140 feet across its strike of 35 degrees. The dip is high to the east. Three brecciated bands, 4, 2½, and 9 feet wide, respectively, contain small pockets of dark brown sphalerite. The limestone in places along the contact has been altered to coarse calcite and actinolite, and in others to a mass of garnet, actinolite, and, probably, some other lime silicates. A little pyrite and some barite occur in the limestone about 3 feet from the granodiorite contact. The cuts on the southwest side of the ridge expose altered limestone. The limestone lies between the easterly dipping contact of the granite mass to the northwest and slaty rocks of the Pend d'Oreille series to the southeast. The granite contact is inclined at a low angle and probably cuts off the limestone at a depth of about 150 feet or less. The limestone has also a very limited length along the strike."

[Reference: Walker, 1934, p. 68.]

Truman The Truman group of nineteen Crown-granted claims covers Truman Hill and extends northward across Lost Creek (*see* Fig. 3). It joins the Tungsten King group, which lies to the north and east. The Truman group is owned by American Zinc Company, c/o D. I. Hayes, 927 Old National Bank Building, Spokane, Washington.

The main showings are between elevations of 2,900 and 3,000 feet on the southeast slope of Truman Hill. They are reached by a road that branches from the South Salmo River road at a point 1,000 feet east of the Lost Creek bridge. This road climbs gradually to an elevation of 2,400 feet and then steeply to the top of Truman Hill. A small showing and an old adit called the Trillion tunnel are on Lost Creek and are reached by about 1,000 feet of bulldozer road running northeast along the south side of the creek from the Lost Creek bridge.

The original location of the Truman showings is not recorded, but the Trillion tunnel is reported to have been driven by L. R. Clubine about 1911. In 1927 the property was known as the Mona and was optioned by The Consolidated Mining and Smelting Company of Canada, Limited, from W. H. Miller, of Salmo. This company drilled four diamond-drill holes totalling 2,073 feet and dropped the option in 1928. The Truman group of seven claims was located in 1946 by L. R. Clubine, who subsequently added more claims to the group. Valley Mining Company, a subsidiary of New Jersey Zinc Company, held the claims under option in 1947 and carried out a programme of geological mapping and diamond drilling. Three holes totalling 624 feet were drilled about 500 feet south and 100 feet east of the top of Truman Hill. In 1949 the claims were optioned by Conwest Exploration Company Limited, and in 1950 they were optioned by American Zinc Company. The latter company subsequently purchased the claims from Mr. Clubine. Diamond drilling completed by American Zinc Company in January, 1954, comprised seventeen holes totalling 7,892 feet. Twelve of these holes were drilled on the south slope of Truman Hill, one hole was drilled about 200 feet southwest of the Trillion tunnel, and two holes were drilled north of Lost Creek. No work has been done on the property since 1954.

The stratigraphic section on the northwest slope of Truman Hill is given in Table III, and the rocks are described in Chapter II. The Reeves limestone forms large bare outcrops on the top and south slope of Truman Hill. The limestone and the underlying Truman member were penetrated by several drill-holes about 500 feet south of the top of the hill. The holes were drilled in a row running approximately north 80 degrees west and six holes were drilled north 15 degrees east at 60 degrees, perpendicular to the plunge of open folds that dominate the local structure. The holes passed through 100 to 200 feet of grey and white crystalline limestone of the Reeves member. The limestone is banded, streaked, or mottled and locally shows intricate contortions. A few feet of dolomite was encountered near the base of the limestone in most of the holes. The dolomite is grey and white, finer grained than the limestone, and not well banded. Locally it is a breccia composed of fragments of light-grey dolomite less than half an inch across, in a matrix of dark-grey to black dolomite.

Most of the drill-holes passed through the underlying Truman member, which is composed mainly of brown argillite, green and brown skarny argillite, limy argillite, and limestone. About 3 feet of white limestone marks the base of the Truman member, below which is grey and brown quartzite of the Reno formation.

Near the Trillion tunnel the structure is complex and a simple stratigraphic sequence cannot be recognized. The Reeves member is mainly grey and white dolomite. Brown micaceous phyllite and white limestone of the Truman member lie south and east of the tunnel.

Outcrops of the Upper Reno quartzite are found about 200 feet southwest of the portal of the Trillion tunnel, where the quartzite appears to be in fault contact with rocks to the east and south. Reno quartzite also forms bluffs east of the tunnel.

The major structure on Truman Hill is the Truman anticline (*see* p. 69, Fig. 4b, and Plate IV). The showings on top of Truman Hill are in the Reeves limestone on the eastern limb of the anticline. This limb dips 30 to 40 degrees to the south and southeast. Small open folds plunge about 30 degrees to the south. The Trillion tunnel is in the western limb of the anticline, which dips steeply and is locally overturned. The western limb is poorly exposed and is complicated by isoclinal folds and bedding faults. The anticline is truncated on the west by a bedding fault passing near the Trillion tunnel and extending northeastward across the valley of Lost Creek. To the east the anticline is offset by a transverse fault thought to be part of the Iron Mountain fault (*see* p. 62). The fault strikes north 30 degrees east and dips steeply. The Reeves limestone on the top of Truman Hill is dropped down on the east side of the fault to an elevation of about 2,700 feet on the south side of Lost Creek northeast of Truman Hill.

Mineralization consisting of disseminated sphalerite and pyrite is exposed in rock cuts at two localities near the top of Truman Hill. At the first locality, just east of the summit, two cuts expose sulphides across 3 feet of beds which dip 35 degrees to the southwest. A chip sample across the beds assayed: Silver, 0.5 oz. per ton; lead, 0.48 per cent; and zinc, 5.9 per cent. The sulphides are in dolomite overlain by grey limestone and underlain by limestone containing a few micaceous layers. The cuts are on the east limb of a small syncline with axis passing through the summit of Truman Hill. At the second locality, 300 feet southeast of the summit of Truman Hill, disseminated sphalerite and galena are exposed in two shallow cuts. Mineralization occurs for more than 15 feet along the southern cut and is about 2 feet thick. The sulphides are in limestone at the crest of a minor anticline. Most of the diamond-drill holes southwest of the surface showings intersected sulphides in a narrow dolomite zone near the base of the Reeves limestone. The mineralization lies within or on the flanks of a syncline with axis passing through the summit of Truman Hill. The extension of this mineralization to the south has not been thoroughly tested by diamond drilling because of a relatively great thickness of terrace gravels covering the bedrock.

The Trillion tunnel is driven south in limestone and phyllite of the Truman member for the first 30 feet, then cuts westward across 10 feet of siliceous argillite to whitish dolomite of the Reeves member. The face at approximately 100 feet from the portal is at a sheared contact between siliceous argillite of the Truman member and dolomite in the Reeves member. Mineralization is in calcareous rocks of the Truman member. The best mineralization now visible is about 20 feet from the portal on the north wall of a small underhand stope. Abundant sphalerite and galena occur at a contact between siliceous argillite and whitish limestone striking south and dipping west. A chip sample across 8 inches of the best mineralization at this contact assayed: Silver, 4.0 oz. per ton; lead, 7.41 per cent; and zinc, 17.1 per cent. Another sample taken at the portal of the adit across a 1-foot shear parallel to calcareous beds assayed: Silver, 3.4 oz. per ton; lead, 5.81 per cent; and zinc, 20.8 per cent. At about 40 feet from the portal the adit leaves the mineralized zone and continues in a direction a few degrees west of south in the overlying argillite and dolomite. No significant mineralization was found in the southern part of the adit.

[Reference: Walker, 1934, p. 67.]

Tungsten King

The Tungsten King group comprises twelve Crown-granted claims covering the valley of Lost Creek between Canadian Exploration holdings and the Truman group. The claims are owned by L. R. Clubine, of Salmo, and R. Oscarson and E. Oscarson, of Spokane. The property is 2 miles from the Nelson–Nelway highway by way of the Lost Creek road. Two roads lead from the Lost Creek road north to the showings and a steep bulldozer road leads south from the Lost Creek road to the level of Lost Creek.

The zinc showings occur in dolomitic limestone near the northwest corner of the Mastadon claim (*see* Fig. 20) and are exposed in a large bulldozer stripping. Tungsten showings are mainly near the northeast corner of the Alfie mineral claim and are exposed in a number of trenches and bulldozer cuts. A small lead showing in limestone south of Lost Creek on the Tungsten King No. 8 fraction is explored by a 35-foot adit.

The Tungsten King group includes two old claims, the Mastadon and the Nellie J., that were Crown-granted in 1907. There is very little rock visible on these claims, and it is not known what showings they were intended to cover. The other claims of the group were located by L. R. Clubine in 1942 and Crown-granted in 1947. In 1942 and 1943 the Consolidated Mining and Smelting company optioned the group and did surface trenching and 1,200 feet of diamond drilling on the tungsten showings. Canadian Exploration Limited held the claims under option in 1952 and did additional stripping and diamond drilling on the tungsten showings. In 1950 the property was optioned to American Zinc Company, who did bulldozer stripping on the zinc showings near the northwest corner of the Mastadon claim and drilled ten short vertical diamond-drill holes on these showings. Additional stripping on the zinc showings was done by the owners in 1953 and again by Canadian Exploration Limited in 1955. This company drilled three short vertical diamond-drill holes to the southeast of the American Zinc holes. At this time a steep bulldozer road was constructed from the Lost Creek road to the level of Lost Creek to provide access to the small showing south of Lost Creek. Canadian Exploration Limited dropped its option early in 1956.

Bedrock on the Tungsten King claims is very largely concealed by gravels in the valley of Lost Creek, but there are fair outcrops in the vicinity of the zinc showings near the northeast corner of the Mastadon claim. Most of the rock units are much better exposed higher on the slope on Canadian Exploration claims. The Tungsten King claims cover the south end of the Quartzite Ridge (*see* Fig. 9), composed of Navada and Reno quartzites. The tungsten showings east of the Quartzite Ridge are mostly in calcareous black Active argillite, and the zinc showings west of the Quartzite Ridge are in Reeves limestone adjacent to bands of Truman argillite. The typically grey and white banded Reeves limestone is altered to buff-weathering white dolomite in the mineralized area. The calcareous rocks are locally altered to skarn. The Truman argillite is brown biotite hornfels variously altered to siliceous green, grey, and white pyroxene-bearing rocks superficially resembling quartzite.

A steeply dipping bedding fault, the Jersey fault (*see* p. 73), is well exposed by bulldozer stripping on the west side of the south end of the Quartzite Ridge. It is a fault that has been traced for over a mile to the north, and on the Tungsten King property brings Reno quartzite into contact with Reeves limestone. Structure in the limestone and argillite west of the fault cannot be determined satisfactorily from the information now available. Attitudes of banding and the distribution of dolomite indicate that the dolomite lies in a rather open south-plunging syncline, though minor folds in the dolomite and some limestone and argillite within the dolomite (*see* Fig. 20) suggest that the structure is more complex in detail. Prominent lineation in near-by quartzite and argillite plunges south 15 degrees west at about 20 degrees and is probably parallel to the plunge of the broad syncline. The syncline is a secondary structure superimposed on an isoclinally folded sequence of Reeves limestone and Truman argillite. Drill-holes indicate that, in addition to the argillite that overlies the dolomite, at least three other bands of argillite appear to be interbedded with limestone beneath the dolomite. From evidence to the north and west it is known that these are anticlinal tails of argillite in Reeves limestone (*see* p. 70).

Sparse zinc mineralization is well exposed in the larger bulldozer stripping near the north boundary of the Mastadon claim. It consists of pyrite and fine-grained dark-brown sphalerite parallel to the banding of white to buff-weathering dolomite. The widest exposures of mineralized beds in the stripped area are about 300 feet west of the small creek. Here mineralized beds in a zone a few feet wide are separated from successive mineralized beds by barren dolomite across a total width of 8 to 10 feet. The sulphides are all somewhat oxidized. Chip samples were taken across the three best mineralized parts exposed. The lowest 15 inches assayed: Silver, *nil;* lead, 0.10 per cent; zinc, 6.5 per cent. This mineralization is overlain by about a foot of very sparse mineralization and then by 38 inches of beds that assayed: Silver, *nil;* lead, less than 0.05 per cent; zinc, 3.4 per cent. The dolomite is poorly exposed above this for 1 foot, then overlain by 21 inches of beds that assayed: Silver, trace; lead, 0.16 per cent; zinc, 1.3 per cent. Another chip sample was taken 5 feet west of the small creek across 27 inches of the best mineralized beds. It assayed: Silver, 0.2 oz. per ton; lead, 0.27 per cent; zinc, 8.4 per cent. Neither the top nor the bottom of the dolomite is seen in the vicinity of the above samples, and the mineralization is incompletely exposed. The dolomite in this area has not been tested by diamond drilling except for hole No. 11. Diamond-drill holes 1 to 10 intersected less than 50 feet of dolomite containing some zinc mineralization. The holes all started in dolomite and were drilled through it to underlying limestone and argillite.

On the south side of Lost Creek, at an elevation of 2,600 feet on the Tungsten King No. 8 fraction, sulphide mineralization occurs in a narrow dolomitized zone at the base of the Reeves limestone. The zone is exposed in outcrop and in a 35-foot prospect adit driven at south 10 degrees west. Mineralization consists of pyrite, pyrrhotite, and some galena within siliceous dolomite. A chip sample across 5 feet of dolomite beds at the face of the adit assayed: Gold, trace; silver 0.1 oz. per ton; lead, 0.94 per cent; zinc, 0.11 per cent. The dolomite zone is 6 feet thick near the portal of the adit but lenses out into limestone about 20 feet to the east. The dolomite is covered by gravels to the west of the adit.

Tungsten showings on the Alfie claim are 2,000 to 3,000 feet east of the lead-zinc showings, between elevations of 2,950 and 3,300 feet. Old trenches and recent bulldozer strippings expose black argillite, limestone, skarn, and aplitic granite; very few outcrops are to be seen away from the workings. The skarn contains scheelite in fine disseminated grains and narrow veinlets. The lowest strippings in a small creek at 2,950 feet elevation expose grey and white crystalline limestone underlain by garnet-diopside skarn dipping 15 to 20 degrees to the southeast. It is possible that the limestone is near the base of the Reeves limestone. The upper strippings about 1,000 feet northeast of the lowest one expose black argillite, and black argillaceous limestone which contains tremolite and is cut by dykes and irregular masses of aplite. These sedimentary rocks belong to the Active formation, and the aplite is probably part of the southern end of the Emerald stock (*see* Fig. 9). A few small masses of garnet-diopside skarn are exposed in the stripping, but their relation to the surrounding rocks is uncertain. About 12 holes have been drilled to test the showings by the Consolidated Mining and Smelting company and by Canadian Exploration Limited. Mainly the holes are in two fans—one drilled from the lowest showing and the other from a point about 500 feet at north 15 degrees west up the small creek from the lowest showing. The holes passed through limestone, brown argillite, and skarn into granite at a depth of several hundred feet. Two holes drilled in the upper strippings went through black argillite and limestone into granite at a depth of about 700 feet. Scattered scheelite was found in most of the holes.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1942, p. 80; 1943, p. 81; 1950, p. 128; 1953, p. 119; *B.C. Dept. of Mines*, Bull. No. 10 Rev., 1943, p. 149.]

APPENDIX.—SUMMARY OF DRILL LOGS

Drill logs summarized here are of holes drilled away from the principal mines. All of the holes except Nos. 8 and 9 were completed in 1952 in exploration for lead and zinc. Holes Nos. 8 and 9 were drilled in 1955 to test a body of limestone for the production of lime. The cores were logged to obtain structural and stratigraphic information and no detailed studies of lithologies and mineralization were made. None of the holes encountered significant lead-zinc mineralization. Locations of the holes are shown on Figure 3. The intervals are in feet.

Hole No. 1.—Vertical. Approximate elevation of collar, 3,275 feet. Drilled by The Consolidated Mining and Smelting Company of Canada, Limited.

0– 28	No core.
28– 330	Black carbonaceous argillite, locally pyritic.
330– 490	Black somewhat limy argillite, locally thinly banded.
490– 650	Interbedded limy and non-limy black argillite.
650– 695	Dark-grey to black, fine- to medium-grained breccia. Angular platy fragments of grey and black argillite up to about 1 inch long in a limy argillaceous matrix.
695– 740	Grey to black limy argillite.
740– 805	Dark-grey dolomite, dolomite breccia, and argillaceous limestone.
805– 975	Grey to black limy argillite.
975–1,100	Black carbonaceous locally graphitic slate.
1,100–1,119	Grey fine-grained argillaceous limestone.
1,119–1,151	White finely crystalline limestone (core box spilled).
1,151–1,192	Grey-brown fine-grained quartzite.
1,192–1,281	Grey somewhat phyllitic micaceous quartzite. Lamprophyre dykes with biotite or pyroxene phenocrysts at 147–148, 225–233, 234–238, 239–240, 540–559, 606–610, 887–888, 981–987. In general, foliation is at angles greater than 50 degrees to the axis of the core, and locally is highly contorted.

Hole No. 2.—Vertical. Elevation of collar, 2,530 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 40	No core.
40– 80	Light-grey to white finely crystalline dolomite.
80– 105	No core.
105– 186	Light-grey locally white dolomite.
186– 232	Grey dolomite.
232– 395	Grey and light-grey mottled* dolomite.
395– 546	Dark-grey and black dolomite locally mottled. Disseminated pyrite 340–370 and 417–475.
546– 570	Highly fractured dark-grey dolomite.
570– 700	Grey very fine-grained mottled limestone, somewhat argillaceous.
700– 850	Light-grey argillaceous limestone with poor cleavage.
850– 930	Light-grey blocky limestone.
930–1,019	Dark-grey mottled limestone.
1,019–1,295	Light-grey blocky limestone.

Hole No. 3.—Bearing, north 30 degrees west; dip, −60 degrees. Elevation of collar, 2,820 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 117	Light-grey dolomite, highly fractured from 84 to 117.
117– 155	Dark-grey mottled argillaceous limestone.
155– 867	Grey phyllitic argillaceous limestone; 725–727 lamprophyre with biotite phenocrysts.
867– 883	Argillaceous limestone with disseminated pyrite.
883–1,015	Very argillaceous dary-grey limestone.
1,015–1,026	Black carbonaceous argillite.
1,026–1,391	Finely crystalline light-grey massive dolomite.

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* The term "mottled" refers to the surface of the core where rounded and irregular areas of one colour of rock are surrounded by more or less continuous areas of a slightly different colour. The mottling results from the pattern of lenticular beds on the cylindrical surface of the core.

Hole No. 4.—Bearing, north 20 degrees west; dip, −60 degrees. Approximate elevation of collar, 2,275 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 100	No core.
100– 160	Dark-grey phyllitic limy argillite.
160– 420	Grey argillaceous limestone with a good cleavage perpendicular to the axis of the core.
420– 585	Grey phyllite, locally limy. Cleavage perpendicular to the axis of the core.
585– 795	Grey mottled limy phyllite. Cleavage perpendicular to the axis of the core.
795– 811	Dark-grey dolomite.
811– 995	Dark-grey mottled argillaceous limestone.

Hole No. 5.—Vertical. Approximate elevation of collar, 3,500 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 120	Light-grey finely crystalline dolomite.
120– 210	Light-grey mottled dolomite, locally limy.
210– 381	Light-grey massive dolomite with few black bands 6 inches to 1 foot thick.

Hole No. 6.—Bearing, north 10 degrees east; dip, −60 degrees. Approximate elevation of collar, 3,350 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 68	No core.
68– 166	Mainly black dolomite with small white spots, Minor light-grey dolomite.
166– 366	Interbedded black and grey dolomite.

Hole No. 7.—Vertical. Approximate elevation of collar, 2,600 feet. Drilled by The Granby Consolidated Mining Smelting and Power Company Limited.

0– 140	Dark-grey finely crystalline somewhat argillaceous limestone. Minor light-grey limestone.
140– 310	Light-grey mottled limestone.
310– 419	Grey and light-grey argillaceous limestone.

Hole No. 8.—Bearing, east; dip, −40 degrees. Approximate elevation of collar, 2,900 feet. Drilled by Purex Lime Co. Ltd.

0– 15	No core.
15– 30	Light-grey mottled finely crystalline limestone.
30– 114	White limestone with local greenish cast. Fine flakes and partings of talc.
114– 436	Light-grey, grey, and dark-grey limestone, locally argillaceous.
436– 488	Grey finely crystalline dolomite.

Hole No. 9.—Bearing, west; dip, horizontal. Approximate elevation of collar, 2,600 feet. Drilled by Purex Lime Co. Ltd.

0– 50	Talus and overburden.
50– 300	Grey argillaceous limestone, poorly cleaved with cleavage nearly parallel to the axis of the core.
300– 405	Dark-grey blocky limestone.
405– 470	Argillaceous limestone, cleavage parallel to the axis of the core.
470– 600	Interbedded grey argillite and limestone with irregular lenses of white quartz.

Hole No. 10.—Vertical. Approximate elevation of collar, 3,050 feet. Drilled by Kontiki Lead & Zinc Mines Limited.

0– 32	No core.
32– 40	Black graphitic argillite with thin white quartz veinlets.
40– 42	Greyish-white felsite dyke.
42– 65	Black thinly banded argillite, bands 35 to 40 degrees to the axis of the core.
65– 90	No core.
90– 690	Black thinly banded argillite, mainly somewhat limy, locally pyritic.
690– 900	Black crenulated argillite.
900–1,136	Dark and light-grey thinly banded limy argillite. Lamprophyre dykes 420–422, 551–552.

Hole No. 11.—Vertical. Approximate elevation of collar, 3,000 feet. Drilled by Kontiki Lead & Zinc Mines Limited.

0– 78	No core.
78–1,022	Monotonous sequence of black carbonaceous argillite and limy argillite. Mainly thin bedded, crenulated with foliation planes 40 to 60 degrees to the axis of the core. Limy and non-limy sections a few feet to a few tens of feet long. Lamprophyre dyke 893–897.

Hole No. 12.—Vertical. Approximate elevation of collar, 2.725 feet. Drilled by Kontiki Lead & Zinc Mines Limited.

0– 14	No core.
14– 914	Monotonous sequence of black carbonaceous somewhat limy argillite, locally pyrititic. Mainly thin bedded crenulated with a poor cleavage parallel to and crenulated with the beds. Lamprophyre dykes 257–265, 267–269, 365–366.

Hole No. 13.—Vertical hole. Approximate elevation of collar, 2,275 feet. Drilled by Canadian Exploration Limited.

0–1,284	Grey and white thinly banded crystalline limestone.
1,284–1,320	Black crenulated argillite.

Hole No. 14.—Vertical hole. Approximate elevation of collar, 3,250 feet. Drilled by Canadian Exploration Limited.

0– 379	Grey thinly banded finely crystalline limestone. Bands approximately at 45 degrees to the axis of the core.
379– 483	Black crenulated argillite with white limy lenses about one-sixteenth of an inch thick.

Hole No. 15.—Bearing, west; dip, —60 degrees. Approximate elevation of collar, 3,100 feet. Drilled by American Zinc Company.

0– 218	Black and white thinly banded crystalline limestone.
218– 290	Black crenulated argillite. Minor thin dark-grey limy beds near 218.
290– 312	Grey-green micaceous phyllite.

Hole No. 16.—Vertical. Approximate elevation of collar, 3,260 feet. Drilled by Canadian Exploration Limited.

0– 151	Grey and white banded limestone.
151– 161	Skarny brown argillite.
161– 944	Grey and white and black and white banded crystalline limestone.
944– 955	Black crenulated argillite.

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